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CONTENTS

PAGE

ANNUAL REPORT OF THE COUNCIL 65

ARKELL, W. J. The Structure of Spring Bottom Ridge, and the Origin of the Mud-slides, Osmington, Dorset 21

BALL, H. W. The Silurian and Devonian Rocks of Turner's Hill and Gornal, South Staffordshire 225

BRAY, A. The Decomposition of Iron Pyrite from Coal Seams 136

CHANDLER, M. E. J. Note on the Occurrence of Mangroves in the London Clay 271

CHANNON, P. J. A New Section at Cowcombe Hill, near Chalford Station, Glos., exposing the Junction of Inferior Oolite and Fuller's Earth ... 174

DAVIS, A. G. *Howchinia bradyana* (Howchin) and its Distribution in the Lower Carboniferous of England 248

———. Note on a Derived Boulder at Warden Point 270

———. and G. F. ELLIOTT. Field Meeting in Sheppey 269

DURY, G. H. A 400-foot Bench in South-eastern Warwickshire 167

EASTWOOD, T. Roofing Materials through the Ages 6

FARRINGTON, A. and G. F. MITCHELL. The End-moraine north of Flamborough Head 100

GASTER, C. T. A. The Structure of the Chalk of Sussex. Pt. IV. East Central Area—between the Valley of the Adur and Seaford, with zonal map 31

HAWKES, L. The Erratics of the English Chalk 257

HAWKINS, H. L. Field Meeting in the Southern Chilterns 255

HAYWARD, J. F. Field Meeting to Hainhault Forest and the Roding Valley 254

HOLTEDAHL, O., T. F. W. BARTH, N-H. KOLDERUP, A. KVALE, and J. F. KIRKALDY. Summer Field Meeting in Norway 203

KIRKALDY, J. F. and E. E. S. BROWN. Alfred Joseph Bull [Obituary] ... 1

READ, H. H. Mylonitisation and Cataclasis in Acidic Dykes in the Insch (Aberdeenshire) Gabbro and its Aureole 237

WARREN, S. HAZZLEDINE. The Clacton Flint Industry : A New Interpretation 107

WRIGLEY, A. Some Eocene Serpulids 177

LIST OF PLATES

PLATE		FACING PAGE
1.	Alfred Joseph Bull, 1876–1950	1
2.	Vertical Air Photograph of Osmington Mud-slides	25
3.	Geological Map of the Chalk in the East Central Area of the Sussex Downs	64
4.	Pebble-tool in quartzite from Lion Point, Clacton	107
5.	Anvil-stone from Clacton	126
6.	Left : Bar-hammer in bone, Jaywick excavations. Right : Bone polished by use at upper end, Clacton	129
7.	Axe-edged implement in bone (Pebble-tool form). Clacton Channel	132
8.	Photomicrographs of Mylonites, Insch, Aberdeenshire	241
9.	Photomicrographs or cataclastically deformed rocks, Aberdeenshire	246
10. 11.	*Howchinia bradyana* (Howchin), Lower Carboniferous	250 252
12.	Photomicrograph of Strained Vein-Quartz, Chalk Erratic	258
13.	Photomicrographs of various Chalk Erratics	262

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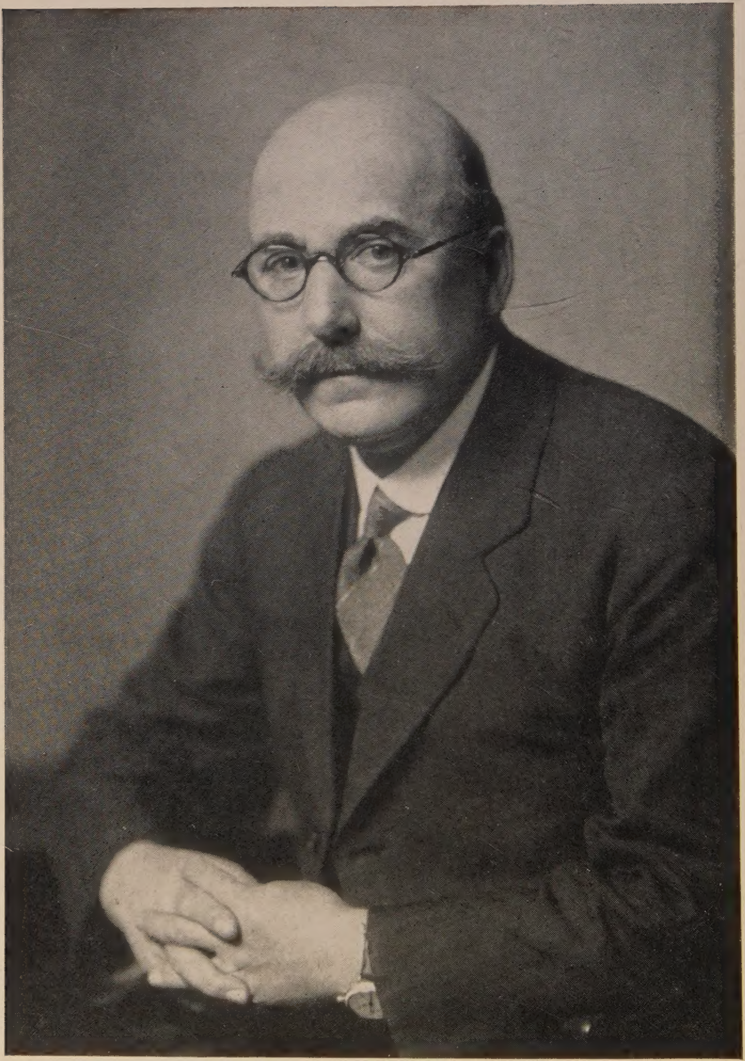

ALFRED JOSEPH BULL, 1876–1950

By courtesy of the London School of Printing and Graphic Arts and of the Editor, PROCESS ENGRAVERS' MONTHLY

Frontispiece

Proceedings of the
GEOLOGISTS' ASSOCIATION

ALFRED JOSEPH BULL,
M.Sc., Ph.D., F.G.S., 1876–1950

By J. F. KIRKALDY and E. E. S. BROWN.

ALFRED JOSEPH BULL, who died, after a short illness, on 15 April 1950, in his seventy-fifth year, joined the Association in 1916. He was elected to Council in 1920, and from 1921 to 1926 served as the Secretary for Field Meetings. President from 1926 to 1928 and Vice-President for the next four years, he well-merited the Foulerton Award conferred on him in 1934 for services rendered to the Association. It was a great satisfaction to his many friends when, in 1946, he was elected an Honorary Member. In the disorganisation caused by the events of 1940, characteristically he assumed the work of the Secretary of the Publications Committee, despite many other pre-occupations, and held that office until his death.

This impressive record of service, however, fails to give a complete picture of the debt owed by the Association to Bull. He was always ready to place his expert knowledge of the choice and reproduction of illustrations at the disposal of the Publications Committee and of individual members. Moreover, he made and supplied many blocks free of all charge to the Association and would take endless pains over the illustration of difficult subjects, such as the Polyzoa shown on Pl. 9 of Volume 43 (1932). The uniformly high quality of the illustrations of the PROCEEDINGS for over twenty-five years is very largely due to him. In his own papers, naturally, he set a standard which many found difficult to approach but they had only to ask him for help and it was readily available, as shown by the thanks given to him at the end of paper after paper.

Bull's scientific distinctions were equally impressive, especially as they were gained in the very different fields of photography, specialised printing, and in geology. Educated privately and then graduating in chemistry from Birkbeck College, he commenced his career as an analytical chemist to the Society of Apothecaries, followed by a post as chemist to the Willesden Waterproof Co. Later, with Messrs. Lumière, he became one of the pioneers of colour-photography. In 1903 he joined the L.C.C. School of Photo-Engraving and Lithography, Bolt Court, Fleet Street, and remained there until his retirement in 1946. Although research work was not regarded by the educational authorities as a proper activity for a technical institute, when Bull became the Principal at Bolt Court in 1912, he soon developed with his staff, technical research work of such quality that the School gained a world-wide reputation for the advances made in photo-engraving, photo-lithography and photogravure. He himself became an international expert on security and currency printing and was consulted by a number of Governments. During the 1939–45 war the School also solved the many difficult problems involved in the large-scale production of graticules of extremely high precision, which were required for a wide range of purposes.

Bull's distinguished work and his human qualities gained him the Presidency of the Royal Photographic Society from 1933 to 1934, the latter being the year of the Fox Talbot Centenary celebration. In connection therewith he made important researches into the history of photography and photo-engraving.

In his early years at Bolt Court, Bull's interest in geology was aroused. In view of his later absorption in major tectonics and geomorphology, it is a little surprising that, as he used to remark laughingly, his early studies were mainly palaeontological. With characteristic thoroughness he attended the full course at the South Western (now Chelsea) Polytechnic and passed the B.Sc. degree in Geology in 1917 as an external student of the University of London. In the following year he was awarded his M.Sc., this time in Physics, for work on colour reproduction, and in 1937 the Ph.D. degree in Geology was conferred on him for one of the best illustrated theses that the University can have received; the subject being his geomorphological work on the South Downs.

When the Weald Research Committee of the Association was founded in 1923, Bull was elected Chairman and he held that office until his death. During this period he was the author or co-author of ten reports, all published in our PROCEEDINGS, and in addition he acted as director or co-director of thirteen Field Meetings to different areas in the Weald.

Three of these meetings were held at Whitsun; to the Eastbourne–Hastings coastline with H. B. Milner in 1925, to the Pulborough district with S. W. Wooldridge in 1930, and to the Central Weald with several directors in 1946. His own work in the Weald was mainly geomorphological; his first publication thereon, in 1925, being on the Mole Gap with S. W. Wooldridge, but he soon transferred his activities to the South Downs. In 1932 he described the several erosion levels recognisable in the Arun Gap and in subsequent papers (1936 and 1940) he traced them along the whole length of the scarp-face of the South Downs and in some cases into the Central Weald. His views on the importance of snow-melt and freeze-thaw conditions during the Pleistocene period in moulding the characteristic land forms of the South Downs, were published in 1940. He did not, however, neglect the solid geology of the area, and paid much attention to the zonal mapping of the Chalk, publishing part of his results in 1938. Also he completed the late F. Gossling's work on the structure of Tilburstow Hill (1948), despite the fact that many men of much less than seventy years of age would have been deterred by the laborious augering involved.

In 1941 Bull prepared a very thorough paper on Pleistocene chronology. It is recalled that, typically, he circulated the manuscript widely before its reading and so attained his object in obtaining a most interesting discussion, with many written contributions. His paper and the full discussion, published in 1942, provide a most valuable summary of current, and often diverse, views on many problems of the Pleistocene.

Bull was also greatly interested in the wider aspects of Tectonics. In 1922 he lectured to the Association on 'Possible causes of mountain folding', and, stimulated by what he had seen and heard during the long Field Meeting to the Alps in 1926, his two Presidential Addresses dealt with the same theme. One attraction of this work was, undoubtedly, that it gave him an opportunity to experiment. Layers of plasticene, putty, etc., were compressed, not as had been done formerly on a rigid base, but in such a way that they could expand downwards as well as upwards. Structures very similar to those seen in the field were produced and, of course, were photographed with great skill. Bull was a strong advocate of the importance of both the Convection Hypothesis and of gravity in producing folded mountain chains. He was, indeed, ever watchful for the effects of gravity, and in Volume 44 (1943) is a photograph, which pleased him greatly, of the Jura-type of folding which he had noted in a sheet of snow sliding down a roof opposite to Bolt Court. His views were at first regarded critically in several quarters but they slowly gained increasing recognition. The last lecture which he delivered to the Association, in December 1949, dealt with 'Gravitational sliding', and, at its conclusion, his audience requested that it should be published in the PROCEEDINGS. This posthumous paper is in part 3 of Volume 61. A number of the points, which he made then, were repeated a few months later, when he was one of the speakers in a joint discussion arranged by the Royal Astronomical and Geological Societies on 'Gravity as a geological factor'.

Our Association was not the only body which benefited greatly from Bull's wise council and expert advice. He served on the Council of the Geological Society from 1935–8, 1942–5, and from 1948 till his death. For the Palaeontographical Society his record of service is even more extensive; member of Council from 1923-7, 1929-32, 1934-7, 1940–4, 1948–9, and Treasurer from 1946-7. He was on the Council of the Mineralogical Society from 1927-9 and 1940-2, then for seven years he acted as its Treasurer and on retirement from that office he was elected a Vice-President. He was also an active member of the Executive Committee of the XVIII International Geological Congress (1948), and when, the same year, the British Association met at Brighton, he was elected a Vice-President of Section C (Geology) and took a lively part in organising and directing the excursions. Throughout the periods quoted there was, in addition, all his work for the Royal Photographic Society and for other kindred bodies of the photographic and printing world. For example, he initiated work on the standardisation of photographic materials and became Chairman of a Committee of the British Standards Institution.

When a life's work, as merely indicated in the foregoing summary, is so full and impressive as Bull's, its record tends to obscure the man himself. Yet Bull had a marked personality with most admirable qualities, which were the key to his manifold achievements. On reflection, perhaps his most constant characteristic was that of 'unhurriedness' in speech, thought and action. Under wartime pressures, in high office, or involved in a controversy, no one found Bull worried or shaken out of his own disciplined pace, which meant progress. The many tasks he was always ready to assume were planned ahead, and 'leave it to Bull' was a sure way of securing a desired end by a promised date.

Bull was an ideal chairman and committee-man, most regular in attendance, persuasive in debate and with a vast experience of the effectiveness of a personal approach before and after a formal occasion. To implement a project, he first made sure that he could carry with him those whose judgment he trusted, then came his plan of campaign and, often without opposition, his object was achieved.

In early middle life some accused Bull of a certain brusqueness. True he was never one to tolerate the foolish, he scorned the chairman or speaker who 'dithered' and, when a matter of principle was involved, he set an ethical standard far above the tactics of expediency. For deliberate wrong or chicanery, he could be ruthless. In later years, without yielding an iota of sound principles, he mellowed with maturity and would talk kindly and humorously of the bothersome folk he met—folk he had helped to an extent which only his intimate friends could guess.

By reason of the amount of work Bull always had on hand, his relaxations were not numerous. He enjoyed the company of friends at night and would take part with zest in scientific talk, the exchange of ideas, and especially the wilder speculations beloved of geologists when they foregather. In accomplishing so much, Bull sacrificed many things which otherwise would have interested him and, in later life at least, music, arts and literature, other than scientific, were put aside; games and sports were outside his ken. His holidays in Switzerland were a real source of inspiration and his love of scenery was profound because in it his two chief interests, geology and the photographic art, coalesced. He attended, for some thirty years, many of the Association's long field meetings, bringing to each some contribution of his own and in turn deriving real pleasure in country new to him and in the company of his friends. He so evidently enjoyed the comradeship of the lunch-time halt or the evening's gathering (whether formal or informal) that we can be sure that this side of the Association's activities gave him in some measure a return for all that he had done for the Association.

Space allows only one anecdote to illustrate Bull's kindly, humorous touch. Dr. Stubblefield recalls that:

> When the Association visited Switzerland in 1926 under Bull's presidency, the party was joined there by Professor R. A. Daly. The British geologists, following the instructions of their eminent leader, Professor L. W. Collet, were all equipped with business-like ice-axes, boots studded with special three-pronged nails, anti-sun-glare glasses, and so forth, but Daly had none of these things and, strangely enough, seemed to get along well without them. The party's appreciation of Daly's feat was ably voiced by Bull at a late stage of the excursion, when in a charmingly worded speech, he presented Daly with a 'pigmy' ice-axe purchased in an Alpine village.

Ever with a great load of work and responsibility, yet Bull could always find the time to discuss the problems of others. Moreover, once he had decided upon a particular course of action, whether relating to policy at Bolt Court, or in one of the Societies, or the necessity of visiting some almost inaccessible exposure, he was persistent in what he believed could be accomplished. He was quite unperturbed by setbacks and would bide his time until he could attain his objective.

The Association has lost a devoted supporter and an outstanding amateur geologist; some of us have lost an intimate friend. We are left with the records of his many achievements and the memory of a personality wise, kindly and mature in its fulfilment.

ROOFING MATERIALS THROUGH THE AGES

By T. EASTWOOD, A.R.C.S., M.I.M.M., F.G.S.

(*Presidential Address delivered* 2 *March* 1951)

SUMMARY.—An account of roofs and roofing materials from Neolithic, Babylonian and Roman times to the present day; and from thatch and wattle, tiles, tilestones, slates, metals and concrete to glass and other substances.

INTRODUCTION

MOST Londoners are familiar with the advertisement of a large Building Society showing a young couple strolling along beneath an umbrella in the form of the roof of a house. We have no such pictures of man and maid in the Stone Age but a roof was just as necessary then as now, for man's primary needs remain food and shelter. In the early days the kind of food eaten by man determined to a large extent the kind of shelter he acquired. With man as a hunter great and uncertain distances would have to be traversed; shelter at the end of a day would tend to be rough and ready. The fisherman would be slightly more settled than the hunter, but it was not until the benefits of agriculture had been discovered that anything like a housing scheme was developed, for even the domestication of animals, such as sheep, oxen, and goats, depended on pastures and the following up of grass led to a nomad life for at least much of the year.

Some of the shelters were 'prefab' in the sense that early man took refuge in natural caves or else he built lean-to shelters against steep or overhanging rock faces, and, where soft sandstones were available, this would lead to artificial caves being made—and so to rock dwellings. In this country many of our caves have been occupied and, indeed, had they not been so utilised, our knowledge of early man and his animal associates would be very scanty; of rock-hewn shelters probably the best are those in the Lower Mottled Sandstone of Kinver Edge about four miles west of Stourbridge. These are crude affairs at best and will not stand comparison with the elaborate rock dwellings and tombs of Petra, hewn in the red sandstone, bordering the great rift at the head of the Gulf of Akaba. Oddly enough the 'fronts' of some of these houses bear a great resemblance to faces of modern dwellings.

We may dismiss at this stage the idea that Chislehurst Caves are ancient dwellings; their origin is the prosaic one of mining though they were indeed dwellings during the war. Caves and soft rocks that nevertheless give scarp faces are not too common, and recourse would have to be made to some kind of building: at first, by erecting branches torn from trees; later, by tying branches together as walls and roofs and covering these with leaves, reeds, rushes and the like, followed at a later stage, perhaps, by the use of the skins of animals.

This form in its turn would give rise to the notion of the portable house of similar pattern, the tent—for use in places where building material was scanty. Felting of fur or of hair scraped from hides, which could then be better tanned and used in a variety of ways as leather, would make a tent easier to carry and erect. In other circumstances the criss-crossing of reeds or leaves into mats would serve as manufactured walls and roofs but in the absence of suitable wood recourse would have to be made to animal bones for a framework, to burrowing or to the erection of rough walls supplemented by the initial hollowing out of the space enclosed. Examples of the foregoing efforts at home building are known as relics in Western Europe if not in Britain and many of them can be studied in present-day use amongst the so-called less civilised communities ranging from the aborigines of Australia, many African tribes, the nomad herdsmen of Asia to the Eskimos in the summer season when snow houses are no longer in use.

As British examples we may quote the Bronze age pit and pile dwellings at Hitcham in South Bucks. These were holes three to seven feet deep and fourteen to twenty feet in diameter with earth thrown up as a bank. On this bank stakes were driven leaning towards the centre and against these turf, branches, etc. were piled to form a roof (*Historical Monuments of England*, *Bucks*., 1911, p. 6).[1] Better known are the Bronze–Iron age pile-dwellings in lakes and palisaded hill strongholds. Examples of these are the Glastonbury Lake Village of Somerset with thatched huts on an artificially raised platform or island, the stone hut circle of Ty Mawr, Holyhead, and the similar one at Scarabrae in Orkney, visited by the Geologists' Association. These huts of stone were the forerunners of the beehive huts where courses of stone were stepped inwards to form a roof. When man became more ambitious as a builder his troubles with roofing began. It is fairly easy to contrive a roof to a walled enclosure of a few feet across, if little or no timber-framing is available by having one wall higher than another and sheeting over the space; if timber is available by its use as rafters or in the erection of a tent-like structure above the walls. A larger room requires big timber for beams or the use of pillars; narrow structures could be roofed directly by stone slabs or arched to one another, or the walls could be gradually brought in until they met at the apex.

Although the roof-span remained a major problem, progress in the building of walls and the like increased with the skill and tools of the builders. Soft yet durable stone soon provided material for temples and palaces while sun-baked clay bricks, bonded with straw, supplied walling for humbler structures. Flooring by slabs of stone possibly preceded the extensive use of slabs on roofs but it is obvious that the search for the one would point to the use of the other, and here we really enter the 'geological age', for elaborate buildings called not only for a roof but for a watertight one at that. There is, however, a great 'unconformity' in Britain between Celtic and Roman buildings and it is necessary to go elsewhere to bridge the gap. It is fairly obvious, however, that the growth of religious, and of various other forms of unified government, provided the urge towards better and bigger buildings and the means of gratifying this urge by gifts (as a sort of spiritual insurance policy) by taxes, and forced labour, etc., for in many cases the high priest of the local temple appears to have had a major share, though discreetly cloaked, in the affairs of government by kings and princes.

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[1] For list of References see p. 20.

It would be interesting to trace the ways in which various peoples tackled the building problems as a whole but we are mainly concerned with roofs. It is evident, however, that there was a good deal of borrowing of ideas though these had to be modified to suit local conditions. We may, however, draw attention to certain salient features beginning with the earliest great builders—those of Babylon, 4000–1275 B.C.

BABYLON TO ROMAN

From its situation at the head of the Tigris–Euphrates delta, Babylon could obtain timber only as rafts from far upstream; there was no local stone but plenty of mud, with the result that bricks and tiles were widely used. Small houses were of sun-dried brick roofed with mud on and reinforced with shrub timber, as they are today in that and similar regions. Larger buildings used sun-dried bricks faced with kiln-burnt and glazed bricks and tiles, bonded with natural bitumen and at later stages with calcareous mortar, and achieved their greater span by the development of semicircular arches. This type of arch was later adopted by the Romans and so spread far and wide.

It is interesting to record that the city of Babylon with an area of 200 square miles had town planning in 2000 B.C. (Fletcher, p. 56) and had skyscrapers of seven stories of glazed brick in different colours; that the Ziggurat which was rebuilt by Nebuchadnezzar was 272 feet square, 160 feet high and crowned with the temple shrine of the god Nebo; that the Hanging Gardens of the King's palace were probably raised on arches 75 feet high and water was raised to them from the river by screws.

Farther north, even when stone was available, the general pattern often followed that of Babylon though the use of stone columns shows affinity with Egypt. For example, the Hall of a Hundred Columns, built 521–485 B.C., was 225 feet square, with brick walls 11 feet thick in which there were 44 doorways and windows. The flat roof of cedar was supported by 100 columns 37 feet high (Fletcher, 1938, p.61).

In Egypt the larger ancient buildings were characterised by massive walls of stone with sturdy close-spaced columns carrying stone lintels to support a flat roof often of stone slabs. For example, the Great Temple of Ammon at Karnack, 1550–323 B.C., had a hall 320 x 160 feet internally and its covered avenues were roofed by enormous slabs of stone and supported 134 columns, about 80 feet high, in 16 rows (Fletcher, 1938, p. 31). The more primitive domestic buildings, however, were of puddled clay and reeds or of sun-dried bricks.

In Greece there is plenty of stone including marble. The Treasury of Alreus (1185 B.C.) is a beehive-shaped tomb 50 feet across and 50 feet high made of overstepped horizontal stone slabs (Fletcher, 1938, p. 79) recalling vaults of brick of similar pattern, but elliptical, such as our early beehive huts and those of Ctesiphon.

In the Hellenic period, 700–146 B.C., the temples, with columned walls when roofed, had a timber framing overlain by overlapping thin marble slabs. Such marble tilestones were made at Naxos, an island in the Aegean Sea, in 620 B.C. (Dobson, 1931, p. 3). It is interesting to note that dressed slabs of oolite are used on the domes of the Victoria and Albert Museum in South Kensington.

On the Parthenon the tilestones were large slabs of white marble with a flange along each side over which marble joint-tiles were fitted. In later temples the tilestones had joint pieces worked out on the same slab. In buildings of less importance the Greeks used terra-cotta tiles of concave upper surface without flanges (Dobson, 1931, p. 3).

The Romans had a variety of rocks at their disposal but their most important building materials were bricks and concrete (*pozzuolana*, —a kind of volcanic dust—formed a hydraulic cement when mixed with lime). During the Etruscan period (750–100 B.C.) some of the vaulting was achieved by the use of large stones. Later (between 146 B.C. and 365 A.D.) more extended use was made of vaulting—some of it in concrete only (Fletcher, 1938, p. 141). Terra-cotta, marble or bronze formed the actual roof covering (*op. cit.*, p. 202).

The Maison Carrée at Nimes, built A.D. 14 and said to be the best-preserved Roman temple in existence, is a hall 50 x 35 feet with a porch of 30 feet and pillars 30 feet high; its roof is of flat pitch.

The Pantheon in Rome, a rotunda erected A.D. 120–4, is circular with internal diameter and height each of 142½ feet. The walls are 20 feet thick of concrete faced outside with brick and tile, and lined internally with marble and porphyry. A hemispherical dome partly in horizontal courses formed the roof (Fletcher, 1938, p. 157) in marked contrast to that of the Basilica Trojan (A.D. 98), with simple timber roof on walls and columns, and of St. Maria Maggiore, Rome (A.D. 432), which has a timber roof to the central nave whereas the two side aisles are vaulted (Fletcher, 1938, p. 227).

ROMAN TO PRESENT DAY

To return to Britain: it is certain that the Romans introduced new methods of building and road making and on some of their buildings clay and stone tiles were used. These arts seem to have decayed when the Romans departed, for Saxon stone buildings are not represented until nearly A.D. 1000 and it is likely that most buildings until then were of wood or wattles with thatched roofs. Bede tells of the burning of a roof of wattles and thatch in A.D. 642 (Innocent, 1916, p. 220).

After the Norman conquest the building of castles and churches went on apace, and the succeeding 400 years witnessed the changes from the heavy massive Romanesque or Norman work through the ever lighter styles of Gothic and Perpendicular. In so far as roofs are concerned these changes are particularly noteworthy in the aisles, cloisters and other relatively narrow places with arches, groins, and vaults of stone culminating in various kinds of fan-vaulting which passed to some of the wider naves and chancels though many retained wooden beams in various forms as roof supports. These ranged from simple beams with king-posts, as seen in scores of our churches, to elaborate hammer beams such as are shown in St. Stephen's, Westminster. The difficulties of obtaining long beams of wood is well examplified at Ely whence the builders of the octagonal lantern scoured England to obtain oak logs 60 feet in length and strengthened roads for their transport.

It is obvious that some kind of waterproof cover was necessary whether the roof supports were of wood, as was generally the case in Norman times, or of arched or vaulted stone, of which we have many glorious examples. In some of the vaulted ceilings the roof was solid masonry slabbed over; in other cases a space was left and an outer timber form of roof constructed. With wooden supports the covering varied from thatch, shingles, tiles, tilestones, slates, lead, and copper down to modern roofing materials. The pitch of the roofs also varied from about 45° in Norman churches to 60° in Gothic styles, later becoming of more moderate pitch and then almost flat in Perpendicular and Tudor. St. Michael's Church at Stewkley (eight miles north of Aylesbury, Bucks) is of interest in several ways. It was built about 1150 in the Norman style with a square tower carried on massive piers between the nave and chancel; the base of the tower houses the choir. The chancel has a simple groined roof made by the crossing of two semicircular arches. In 1684 the outside roof of nave and chancel was lowered to a pitch of about 15° from the horizontal whereas the original slope approximated to 50°—a slope which suggests thatch or tiles. The church records for 1696 show the purchase of 650 tiles, presumably for the repair of the flattish roof, though an engraving of 1776 suggests a leaded roof for the chancel. In 1862 these roofs were restored to the original pitch and they are now clothed in red flat tiles. The present interior roof of the nave is a barrel roof with slender rounded king-post on a square and presumably old beam. Many other churches show various modifications of the original; that of the neighbouring church of Wing for example; this is Saxon with superficial alteration to the apse though the nave has become Decorated. Cathedrals show even more modifications but we must leave this interesting subject and return to roofs and their coverings. These were always affected by costs and the availability of local materials. Since tiles can be made in most counties it is not surprising that they have been long and widely used. Next come the tilestones with slates much later except in slate localities. Lead has been used extensively all through the ages on large churches.

We may now consider in some detail the various roofing materials.

MATERIALS

Wood. In addition to forming roof supports and a base for other kinds of protection cover, wood has also served that purpose as riven or sawn boards and as shingles. Pliny relates that 'Rome was covered with shingles, that is small pieces of thin boards, at the time of the war with Pyrrhus' (Aldrich, 1789, p. 9). While shingles may have been used in Roman and Saxon Britain, when the use of timber for all kinds of building construction was common, the first mention on a large scale is that of the roof of Salisbury Cathedral, completed in 1258 (Dobson, 1931, p. 6).

It is recorded (Innocent, 1916, p. 185) that in 1314 certain royal manor houses roofed with wooden shingles were in great need of repair and that these shingles might be replaced by stone slates or earthen tiles at less cost. Long Preston Church, near Skipton, was shingled in the fourteenth century (Whittaker, 1878, p. 512); about the same time Appletreewick Manor, in the same district, was rebuilt and slated (probably with tilestone).

Shingles appear to have gone out of fashion about this period, but are still used as, for example, on new farm buildings, near Hornby Castle in Lunedale, and on the steeple of the church in Apsley End, north of Watford, which appears to be clothed in wooden shingles.

Tiles. In the manufacture of tiles a more careful selection of the clay is necessary than in brick-making: it must be as homogeneous as possible; there must be no stones nor lumps. Further, the product when baked should retain its shape, be free from cracks, should neither transmit nor unduly hold moisture such as to cause it to flake during frosts, and, as with any other kind of material, be as durable as possible.

The Romans are usually credited with the introduction of burnt clay tiles into Britain, but an instance is quoted from East Tilbury where, on the present foreshore of the Thames, the remains of four pre-Roman circular huts 11½ to 20 feet in diameter were discovered; each had a frame of pointed stakes, supporting wattle work, planked floors, and roof tiles of burnt clay (Lloyd, 1931, p. 8). Be that as it may, the Romans spread the use of tiles and those that they introduced were of Italian pattern which has survived to the present day on the continent and has been imported in large quantities from Courtrai; they are now made in Britain.

The Roman tiles, used extensively at Verulam, near St. Albans, are about 15in. x 12in. with a turn up of 1½in. on the long sides, over which rests a semicircular cover tapered to fit into its neighbour, as do the tiles, with a lap of about 4in. Their weight and absence of fastenings suggests they were laid on a roof of low pitch.

No direct descendants of the Roman tiles are known from Saxon Britain, and it is uncertain when the plain tiles used on medieval buildings were first manufactured; but an attempt seems to have been made in 1212 to make the use of tiles compulsory in London on account of thatch fires (Dobson, 1931, p. 6).

It is known that Alexander Tigulator, a tyler, lived at Colchester in 1301 and it is fairly certain that tile making was an important industry in Colchester by 1425 with an Act of 1477 regulating brick and tile making (Dobson, 1931, p. 9), with respect to weathering of clays from 1 November to 1 March, the separation of stones and chalk from the tile-making material, and fixing the sizes as 10½ x 6½ x ⅝in. The Act was repealed in 1856 but similar sizes are in use today. Tile making still thrives around Colchester.

Tiles were made at early dates in other places; those for Guildford Castle were made at Shalford, and it is known that tiles were made at Hull and Beverley in the thirteenth century.

The waved tiles, known as pantiles, of which good examples may be seen in Tunbridge Wells, were introduced into Britain from the Netherlands where they were made from the fifteenth century onwards. Such tiles were first made in England at Tilbury about 1700 and were said to be as good as, if not superior to, those of the Dutch (Dobson, 1931, p. 6).

In the past, tiles were made in half the counties of Britain and, though there are still many works scattered through the country, there has been a considerable concentration—particularly to the coalfields where high Coal Measures, such as Etruria Marls, are present. There are, however, still considerable tileries in the Weald, near Cheltenham and at Bridgwater in the west.

An attempt was made some years ago to make tiles from Cambrian shales at Chapel End, near Nuneaton, but it was not a success owing to warping of the product. From Cambrian to fairly recent brickearth, clayey rocks of all ages have been used, or tried, with emphasis on Coal Measures, Lias, Lower Cretaceous, and Eocene and, to a less extent, on those of Old and New Red Sandstone and recent deposits.

The numerous old, red-tiled barns in Middlesex point to a former local industry; there are very good examples of these at Headstone, near Harrow, and about Ruislip.

Tilestones. Under this heading are included rocks which owe their fissile character not to cleavage but to natural bedding, *i.e.* mainly to depositional rather than to induced characters, though occasionally some rocks are suitable for roofing because of close-set jointing, as, for example, the igneous rock of Corndon Hill in Shropshire. On the western faces of that hill the thinly laminated rock appears to dip 35° west (Murchison, 1839, p. 277); according to a fifteenth century poet the rock was used in a house at Llandrinis (North, 1946, p. 53). Some schists are sufficiently fissile for roofing purposes, as in parts of Norway and in the Scottish Highlands, but, as a rule, tilestones are sandy shales or shaly sandstones or limestones. Parting is facilitated by muddy films or by the presence of mica, but if the parting planes are closer than about half an inch, the tilestone is not likely to be very durable; on the other hand, if more widely spaced than an inch, the slabs will be too heavy for ordinary roofs but will serve for covering outhouses, for flags and the like.

Slabby rocks of all ages have been used locally for tilestones; some have been distributed over fairly wide areas as, for example, those from the Coal Measures of Lancashire and Yorkshire and those from the oolites of Lincolnshire and the Cotswolds.

Amongst the oldest strata are the hard Ordovician–Silurian shales of the Southern Uplands which provided rather thick and heavy roofing tilestones in the Peebles area and also on the eastern side of Loch Ryan (Scottish Slates, 1940, p. 1). Farther south slabby Silurian shales were worked extensively around Corwen in North Wales and a very micaceous Ludlow sandstone at Cilmaenllwyd, about six miles north of Ammanford.

The Tilestones at the base of the Old Red Sandstone, as the name indicates, have yielded roofing and flag stones; higher beds have been worked fairly extensively in Orkney, Caithness and Angus, and also in the Eppynt Hills between Builth and Llandovery.

Much greater in importance than any of the above are the fissile sandstones of Carboniferous age, particularly in the north of England; of these the Slate Sills in the upper part of the Limestone Series about Alston may be mentioned, though even more widely used were the sandstones of the Lower Coal Measures especially of north-east Lancashire and west Yorkshire, where for some hundreds of years they were quarried and occasionally mined. In addition to many churches and monastic buildings and the halls of the landed gentry, these Coal Measures 'slates' were used extensively on the houses and barns of yeoman farmers and on general property of all grades. Their use survived well into the industrial era and 'slates' 300 years old are still sound. As roofs to outhouses in the form of thin flags or slabs they were commonly used as late as 1900. Examples of all these uses may be seen in the Burnley area, east of the Pennines and in Derbyshire.

Farther south there are no such rocks until South Wales and neighbouring English territory is reached; here the grey Pennant Sandstone not only provided building stone but also, in some localities, sound roofing material. Examples may be seen on old buildings in the Forest of Dean, but evidence of much earlier use was provided by the Roman villas at Llantwit Major (four miles south-south-west of Cowbridge, Glam.) and at Chedworth (four miles west-south-west of Northleach); in both these cases oolite was used for ridge tiles and at Chedworth some of the 'tiles' were of Old Red Sandstone.

In the Permian the name Marl Slate, given to shaly rock beneath the Magnesian Limestone, suggests use as a tilestone, but fissile sandstones in the Trias, good enough for 'slates', are not common, and though the thin beds of limestone in the Rhaetic and Lias have been much used for flags, they seldom provide good roofing stone. Some of the limestone of the Lower Lias at Queen Camel, near Sparkford, and near Burley Dam, in Shropshire, have furnished tilestones as have thin flaggy beds in the Marlstone at Chacomb, near Banbury (Woodward, 1893, p. 295).

On the other hand the fissile portions of the Oolites have been used extensively on all classes of buildings. For example, the basal part of the Lincolnshire Limestone has been quarried and mined for hundreds of years until recently, mainly around the village of Collyweston, near Stamford—hence the name Collyweston Slates. Collyweston Slate was used on a large barn built at Peterborough in 1307 and destroyed in 1900 (Innocent, 1916, p. 173). Farther south, beyond the range of the Lincolnshire Limestone facies, that portion of the Inferior Oolite above the Northampton Ironstone has been quarried round Duston, near Northampton, for 'slates' (Thompson, 1910, p. 471). The Inferior Oolite of the north Cotswolds has yielded thick and heavy 'slates' at Snowhill, Condicote and Lower Swell.

Rivalling those of Collyweston are the 'slates' of the Great Oolite in the Cotswolds. The Stonesfield Slate at the base of that limestone was mined around Stonesfield, near Witney, and as late as 1910 two quarries worked these slates—at Througham, near Bisley (Bisley Slates), and at Chalk Hill, near Eyeford. The condition recurs at intervals as far as Minchinhampton, near Stroud, and at one time there were considerable slate workings on Sevenhampton Common, just north of Andoversford. At the present time some slates are quarried at several points in the area Andoversford–Stow-on-the-Wold–Bourton-on-the-Water (Arkell, 1947, pp. 142–9). Farther east part of the Taynton Stone of the Great Oolite is occasionally fissile producing the Fulwell Slates which are obtained a mile south of Enstone.

The top part of the Great Oolite, known as the Forest Marble, has furnished great quantities of coarse roofing tiles; these, unlike the Stonesfield Slate, do not require frosting before splitting but peg holes are difficult to make. The chief centres were at Poulton (midway between Cirencester and Fairford) and between Burford and Lechlade (Arkell, 1947, p. 147); they were also quarried near Tetbury and Bradford-on-Avon (Woodward, 1893, p. 485).

At Buckland Warren, twelve miles south-west of Oxford on the Faringdon road, the Corallian is fissile enough to yield the flags and slates known as Pusey Slates.

At a much higher level tilestones have come from the Slatt Beds—thinly bedded limestone in the Lower Purbeck—near Weymouth.

In south-eastern England the best-known tilestones are the Horsham Stone obtained from thin belts of sandstone low in the Wealden Series. They are rather heavy, brownish stones of somewhat irregular shape. Examples may be seen on older buildings in Kent, Surrey, and Sussex.

Tilestones like slates may be nailed to the rafters, as was the case with the small irregular hexagonal ones used at the Roman villa of Chedworth, but more often pegs were used. These were usually of wood—oak, deal or, preferably, elder—but occasionally the bones of sheep were favoured.

Slates. The general public and many builders are apt to include any roof covering cut to shape and laid in overlapping fashion, as slate. Geologically, the term slate is restricted to rocks that have developed a fissile character as a result of the reorientation of rock particles, accompanied, as a rule, by the introduction of new minerals, due to intense horizontal earth pressure. Such a slaty cleavage is usually at a high angle to the bedding of the original sediments which may now appear as bands on the cleaved face. Not all rocks affected by slaty cleavage, however, provide roofing material. For example, the formation known as the Skiddaw Slates is thousands of feet thick and slaty cleavage is common but the rocks usually break into splinters or spars rather than into slabs suitable for roofing.

In Britain true slates, in the geological sense, and of roofing quality, are restricted to pre-Carboniferous strata. Since the latter in their turn are restricted in general to the mountainous, barren and sparsely populated regions towards our western seaboard, or to Scotland, it is not surprising that, in the days of poor roads, tilestones (fissile along the bedding planes) from younger strata, especially if available near the building sites, should be in demand. Improved transport, in its turn, has led to the concentration of output from certain quarries and to the closure of others which, though reasonably accessible, yielded slates durable enough but with far too many of small sizes, or gave slates of good size but of poor quality. Slaty cleavage, as may be expected, affects all kinds of rocks but those which pressure will convert into good roofing slates, are usually argillaceous though excellent slates have been derived from volcanic ashes as, for example, the Borrowdale Slates of the Lake District. In some of the Welsh slates cleavage laminae may be no thicker than a visiting-card but such thin-splitting material is no good for roofing purposes; on the other hand, thick slates add to weight and cost. On the whole a slightly sandy shale is likely to provide a better slate than a purely argillaceous; it will be stronger, and its slightly rougher surface will prevent the upward capillary creep of water between the slates on a roof.

In strong rocks, such as indurated sandstones, the cleavage planes are so far apart that nothing better than slabs will result. It is obvious, then, that homogeneity of the strata is desirable; even then the amount of waste is ten times higher than the production of good slates.

Given a thick belt of slate, its position and lie determine method of work. A highly inclined belt on a hillside may be worked on successive benches as at Bethesda; on low ground a deep quarry is the usual result as at Nantlle. A gently inclined belt is likely to require mining as at Blaenau Ffestiniog.

It is obvious that the older the rocks the more they have been subjected to earth stresses through the ages, and, since all these pressures are not from the same direction, the qualities impressed at a certain stage may have been destroyed later. For example, some of the pre-Cambrian movements were on north-east–south-west lines resulting in folding along north-west–south-east axes with cleavage parallel to these axes. Later movement—such as the Caledonian which took place in Old Red Sandstone times and approximately at right angles to the former, produced excellent slates from Cambrian, Ordovician, and Silurian strata—may have destroyed by introducing cross fractures what had, in earlier times, been good pre-Cambrian slates. That it did not do so in all cases is proved by the excellence of the slates of the Brand Series of Charnwood Forest, worked until the end of the last century and still of such repute that old buildings are pulled down to obtain slates for new structures.

The pre-Cambrian slates of Charnwood have been mentioned. There are other ancient slates in Scotland usually referred to pre-Cambrian. These occur in the west, giving the Easdale Slates near Oban and the Ballachulish Slates around Loch Leven and at various places along the Highland Border from Loch Lomond towards Stonehaven; here the most famous locality is Aberfoyle. These belts are still actively worked but those in the Banffshire area, south of Macduff on the coast, are no longer wrought. Scottish slates are usually dark and minutely wrinkled.

Most of the slates produced in Britain, however, come from the Cambro-Ordovician strata bordering the Snowdon region of North Wales where the trade has been concentrated into the huge quarries of Bethesda and Nantlle and the mines of Blaenau Ffestiniog and Corris. Most of these are blue or purple but some are red or grey. Slates from Bethesda were used on the roof of St. Asaph Cathedral in the time of Charles I and when, after 250 years, the roof was stripped on account of timber failure the slates were still sound (North, 1946, p. 103).

There has also been a certain amount of slate produced in South Wales—chiefly in the Prescelly area.

In the Lake District there are two main sources: (a) the Borrowdale Volcanic rocks producing greenish grey slates chiefly from the Honister and Coniston areas, and (b) the blue, or Burlington, slates from Silurian strata in the Grisebeck area about four miles northwest of Ulverston. In the past many small quarries worked intermediate strata south of Coniston.

The famous Delabole Quarries near Boscastle in Cornwall produce the youngest slates in the country; they include grey, green and rustic slates.

Metal Coverings. On account of its easy working properties and freedom from corrosion, lead has always been popular for roofing either as a complete cover or to supplement other materials.

Much of the output of British lead mines must have gone on to the roofs of churches. It may be noted that some of the earlier cathedrals had roofs of very low pitch on which lead could be used freely, whereas, with a pitch of over 50°, lead is inclined to creep and its place is taken by tiles, though part of the North Aisle of Canterbury Cathedral with a pitch of 50° is covered with lead which has not been renewed since early in the sixteenth century (Dobson, 1931, p. 56). This is unusual for little of the medieval lead is left on the roofs of England today though much of the spire of Ashwell Church (*c.* 1400) still has its original lead (Powys, 1929, p. 144). Most of the leadwork on church roofs was recast and relaid in the eighteenth and early nineteenth centuries. The medieval plumbers used narrow short sheets of cast lead much thicker than in later work and laid this lead on 3–4in. wide oak slats spaced 1–2in. apart. It is said that lead will quickly decay on new oak or cement, deal being recommended for repair work, and that cast lead will last longer than milled lead (Powys, 1929, p. 145). Lead is common on roofs and the examples quoted of St. Paul's Cathedral, London, and most of York Minster, may be supplemented anywhere.

Bronze was occasionally used by the Romans (Fletcher, 1938, p. 202) but copper has not been used so long or extensively as lead, though it is by no means uncommon, and its weathered green surfaces are conspicuous. It is used on the North Transept of York Minster (Powys, 1929, p. 149), on part of Norwich Cathedral, on the Old Bailey, on the Imperial Institute, on Giggleswick School observatory, and on countless other buildings.

The use of zinc sheeting is of fairly recent date; it is thinner, lighter and, at first cost less than lead; it is commoner on domestic rather than on large buildings. Zinc, for galvanised and corrugated iron, is extensively used for roofing various structures including houses in some of the colonies. The non-galvanised corrugated iron, made available during the wars in heavy curved sheets which could be bolted together as walls and roof without further framing, has to some extent been replaced by similar shapes in asbestos cement. From the latter are fabricated large warehouses and hangars.

The most recent of the metals to be used in roofing is aluminium and its alloys; apart from pre-fabricated houses, the most extensive use known to me is on the dome of the Festival of Britain buildings.

Other roofing materials. Various kinds of felt, water-proofed with tar, bitumen, rubber, or cement, and supplied in rolls or cut into 'shingles', are commonly used on temporary buildings, but on large structures, particularly where a flat or low pitched roof is desirable, concrete sheathed in metal or asphalt appears to hold sway. In speaking of this artificial stone another in the form of glass should not be overlooked. In addition to such obvious structures as greenhouses and glasshouses, ranging from those of botanical gardens to such a monster as was the Crystal Palace, it should not be forgotten that glass is used with other materials in roofing many factories. That its use is not ultra-modern is indicated by the fact that, on the serrated roofs of the huge weaving sheds of Lancashire and Yorkshire, glass contributes more than 25 per cent of the roof covering.

CONCLUSION

In reviewing the various kinds of roofing and building materials from the distant past to the present it is clear that, while methods of application have improved along with the evolution of materials in the passage of years, many basic factors remain virtually the same. Moreover, in some parts of the world, there has been very little change through the centuries.

Early builders used mud as mortar to bricks or as matrix to rough stones for walling; then came burnt lime and dressed stones. The Romans went further by combining these matrix materials into cement, their favourite mud being *pozzuolana*, a volcanic dust which they mixed with lime, ground potsherds, etc. Many of their walls and arched passages are faced with brick or stone around a core of concrete made from local aggregates and poured into a frame. The walls of Verulam at St. Albans are interesting in this connection as they are built of flint rubble with courses of brickwork.

The use of mud on roofs was stabilised by mixing with brushwood, as, for example, in the Middle East from ancient times to the present day. This usage probably developed into wattle with sticks and reeds in place of brushwood, and both may be regarded as ancestors to reinforced concrete, for the purpose of the sticks was to strengthen the mud just as steel rods are employed in concrete though another function of leaves and straw may have been to permit drying without shrinkage. Lath-and-plaster work is also a lineal descendant of wattle.

From ancient to fairly recent times, the method of constructing houses and the like in the clay areas of the country with little building stone, was to use wattle or bricks in a frame of wood. In some of the earliest the builder selected pairs of curved tree trunks (crucks) to form the ends which were connected by horizontal baulks with some diagonal struts. Gradually a rectangular pattern of timber framing evolved, as in the ordinary black-and-white houses of Cheshire and Salop, and this, with further decoration, gave such elaborate buildings as Little Moreton Hall on the Stafford–Cheshire border. In some of the earlier buildings there was no sharp distinction between walls and roof. This is equally true of stone buildings as, for example, the Hebridean huts and the Priests' Cell (*c.* 700) at Dingle, Ireland (Richards, 1938, p. 7), and those of thatch and wattle as, for example, Teapot Hall at Dalderley, near Spalding, with very low side walls and a roof long from eaves to ridge. St. Mary's Hospital, Chichester, is another example; it was built late in the thirteenth century, has a nave of 84 feet and aisles with side walls only 6 feet high (Richards, 1938, p. 15).

These square timbered houses may be regarded as ancestral forms of the huge steel constructions of today save that the steel frame is usually hidden by a facing of brick, stone or concrete.

Thatch in some form or other is one of the most ancient forms of roofing, particularly of houses, though it was also used for churches as at Freshwater, I.O.W., and in Norfolk. It is commoner today than many people suppose and may be seen alternating with oolitic tilestones, tiles, Welsh slates and, alas, corrugated iron, in many Cotswold villages, as, for example, at Long Handborough near Woodstock. Nevertheless, it is surprising to read in the *Sunday Express* of 17 December 1950, that there are still 9000 thatchers in this country. Their main use, however, must be largely in repair and renewal work, and for covering ricks.

Coming now to the solid roofing materials, it is unlikely that tilestones will come into common use again. This is to be regretted in that tilestones harmonise with the local walls and country to a greater extent than do most slates and tiles, though some modern tiles pass muster fairly well as, for example, the grey buff 'Cotswold' tiles employed on new houses in such limestone villages as Burford and Aynho. For higher class work and for repairs there is, however, a considerable demand for the Cotswold slate got at quarries northwest of Bourton-on-the-Water; they have been used on the new police headquarters at Banbury (Arkell, 1947, p. 142).

Tilestones began to go out of fashion when true slates came into prominence during the industrial revolution. Slates, in their turn, appear to have passed their heyday by the beginning of this century when 662,000 tons a year was the highest output. This fell gradually but drastically in the next twenty years to less than a sixth of that figure; while it is true that the next twenty years show improvement, the output was but 283,538 tons in 1938. These figures relate to output from the quarries of Great Britain as a whole; to these totals Wales contributed more than three quarters.

There is certainly no lack of durable material so far as slates are concerned, and the decline must be due to fashion and price or both; the former is a matter largely for architects; the latter is a question of trade.

We have seen that tiles have been made from clays for over 3000 years, and it is unlikely that the demand for them will decrease for permanent buildings of small and moderate sizes. On the other hand their place, and that of slates on large buildings, is likely to be taken by concrete with some kind of waterproofing skin.

With lead at its present price of over £140 a ton and no recent discoveries of large orebodies, it is unlikely that it will be used extensively again as a sheathing to roofs. Whether its place will be taken by aluminium or plastics remains to be seen.

Finally, if this address stimulates an interest in roofs, it will have served its purpose and there certainly is ample material everywhere for study.

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THE STRUCTURE OF SPRING BOTTOM RIDGE, AND THE ORIGIN OF THE MUD-SLIDES, OSMINGTON, DORSET

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CONTENTS

		PAGE
1.	Introduction	21
2.	Structures in the Upper Jurassic and Wealden Rocks	23
3.	Structure of the Cretaceous Syncline	24
4.	Origin of the Osmington mud-slides	27
5.	Relation of the Angular Flint Gravel to Clay-with-Flints	29
	References	30

SUMMARY.—A hitherto undetected normal fault explains several anomalies in the complicated geology around Osmington Mills, including the origin of the 'mud glaciers'. The Angular Flint Gravel is shown to be a weathered form of the Clay-with-Flints.

1. INTRODUCTION

SPRING Bottom Ridge is a long Chalk down which runs east-and-west at the back of Ringstead Bay, about half a mile from the coast. At the east end it merges in the Chalk uplands called Chaldon Down, of which White Nothe is the seaward boundary. At the west end it is cut off by the Osmington Mills stream valley. The length of the ridge between these two extremities is just under two miles and the average width about half a mile. West of the Osmington Mills valley there are two small Chalk outliers, showing where the ridge formerly continued but is now obliquely truncated by the coast. The interesting glacier-like mud-slides occur in this westerly extension of the ridge, between the Mills valley and Black Head.

Strahan's mapping in the 1890's (Sheet 342[1]) showed that the existence of the ridge is due to a west–east synclinal fold in the Upper Cretaceous rocks, which is superimposed on and parallel to the south limb of the Upton Syncline in the Upper Jurassic and Wealden rocks. Immediately to the south, in Ringstead Bay, both the Upper Jurassic and the Upper Cretaceous rocks are thrown into anticlinal folds, of which the axes are parallel but not coincident. The axis of the pre-Gault Ringstead Anticline runs up to a quarter of a mile south of the post-Cretaceous anticlinal axis, and its crest was eroded away before deposition of the Gault.

So far the structure, as already established by Strahan, is simple; but at several points there were known to be complications: for instance, there are exposures of vertical Chalk and Upper Greensand at Southdown Farm; an old pit in Chalk many feet below its expected

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[1] The Sheet-numbers refer to the Geological Survey colour-printed maps, 1 inch to 1 mile.

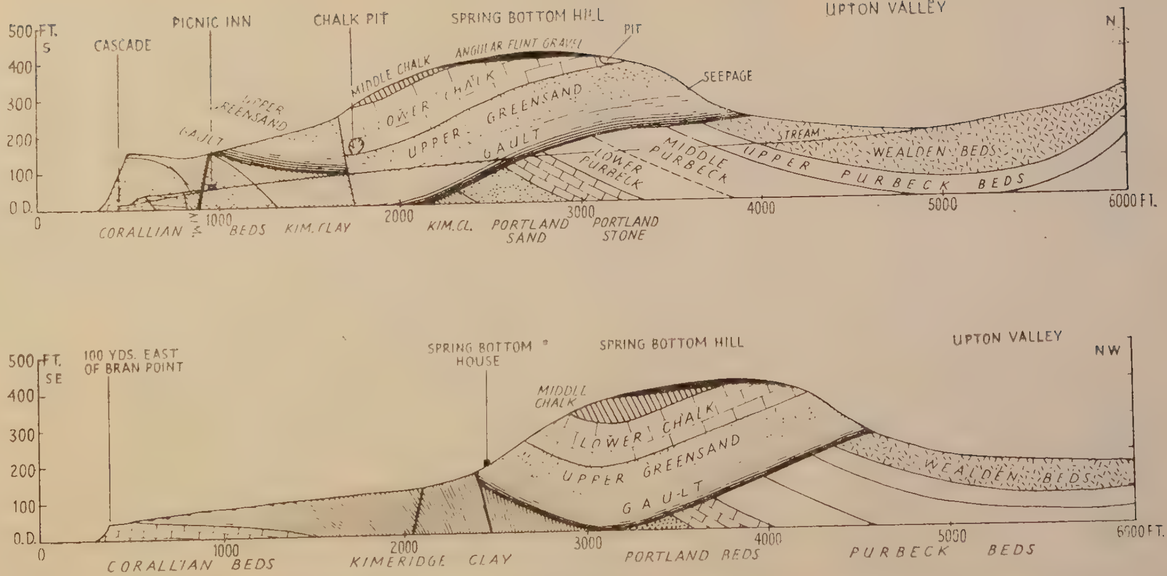


FIG 1.—(*Above*) Section N.–S. along the Osmington Mills stream, with the section of Spring Bottom Hill projected on to the same plane.

(*Below*) Section NW.–SE. through Spring Bottom Hill. (Vertical scale twice the horizontal).

position on the east side of the Osmington Mills valley; a jumble of boulders, apparently of Upper Greensand, in the stream above the Mills; and a mosaic of faults and folds in the Jurassic rocks on the foreshore at the Mills.

Although the Weymouth and Swanage memoir (Arkell and others, 1947) was largely written at Ringstead Bay, the structure of Spring Bottom Ridge was not investigated in the detail it deserved, for two reasons. First, energies and attention were at that time focused on the more spectacular structures along the Ridgeway Fault, which had to be mapped, by means of augering, on the 25-inch scale. Secondly, the work was being written against time, under the shadow of the Munich crisis and the Russo-German pact, in the hope that it might be completed and printed before war broke out. (The memoir was completed by the autumn of 1939 and in proof by Christmas, but, owing to the war, publication was delayed until 1947.)

Since the war the problems of the ridge have been pondered anew and the ground has been re-examined in detail. The new facts and revised interpretations are represented in the accompanying geological map (Fig. 4) of 6-inch Sheet, Dorset LIV, NW. and a strip of Sheet LIII, NE. I am indebted to Mr. W. T. Wright for drawing the map and Figs. 1 and 2.

2. STRUCTURES IN THE UPPER JURASSIC AND WEALDEN ROCKS

The cliff sections always made the structure so clear that nothing important has been added along the coast. The detail of the complicated mosaic at Osmington Mills is shown in the Memoir (*op. cit.*, p. 283, fig. 63) and is, as there suggested (p. 282), no doubt due to the superimposition of Tertiary and intra-Cretaceous movements, for the new interpretation reveals that the locality lies on the axis of the Spring Bottom Syncline and the Ringstead Anticline.

North of Osmington Mills some new exposures have thrown light on the celebrated V-shaped outcrops of Purbeck and Portland Beds on either side of the stream, detected and mapped by Strahan (Sheet 342). Home Guard trenches on the east side threw up Beef Beds and some pieces of Cinder Bed (Middle Purbeck), thus confirming Strahan's mapping. A soakaway pit for a new house on the west side and farther south, however, produced Gault Clay where Strahan had inferred Kimeridge Clay (the spot is marked on Fig. 4); and this and an exposure of Portland Limestone in the east bank of the stream a little farther south have led to the abolition of Strahan's small diamond-shaped inlier of Kimeridge Clay along the Mills stream.

At South Down Farm and Ringstead Dairy the structure of the Portland and Purbeck outcrops is not so simple in detail as represented on the maps. The permanent bogs on the east side of the dairy and in Pit Copse must be due mainly to seepage from the top of the steeply tilted Gault at coombe heads, but the larger size and greater wetness of the bog east of the dairy may be partly due to a fault in the Jurassic rocks, bringing Portland Beds against Kimeridge Clay immediately under the Gault. The presence of such a fault, throwing down west, is indicated by the interruption in the strike of the Portland Beds, which are shifted south with the introduction of Purbeck tufas and slatt on the west side. A prolongation of this fault southwards may account for the most easterly of the Ringstead ledges.

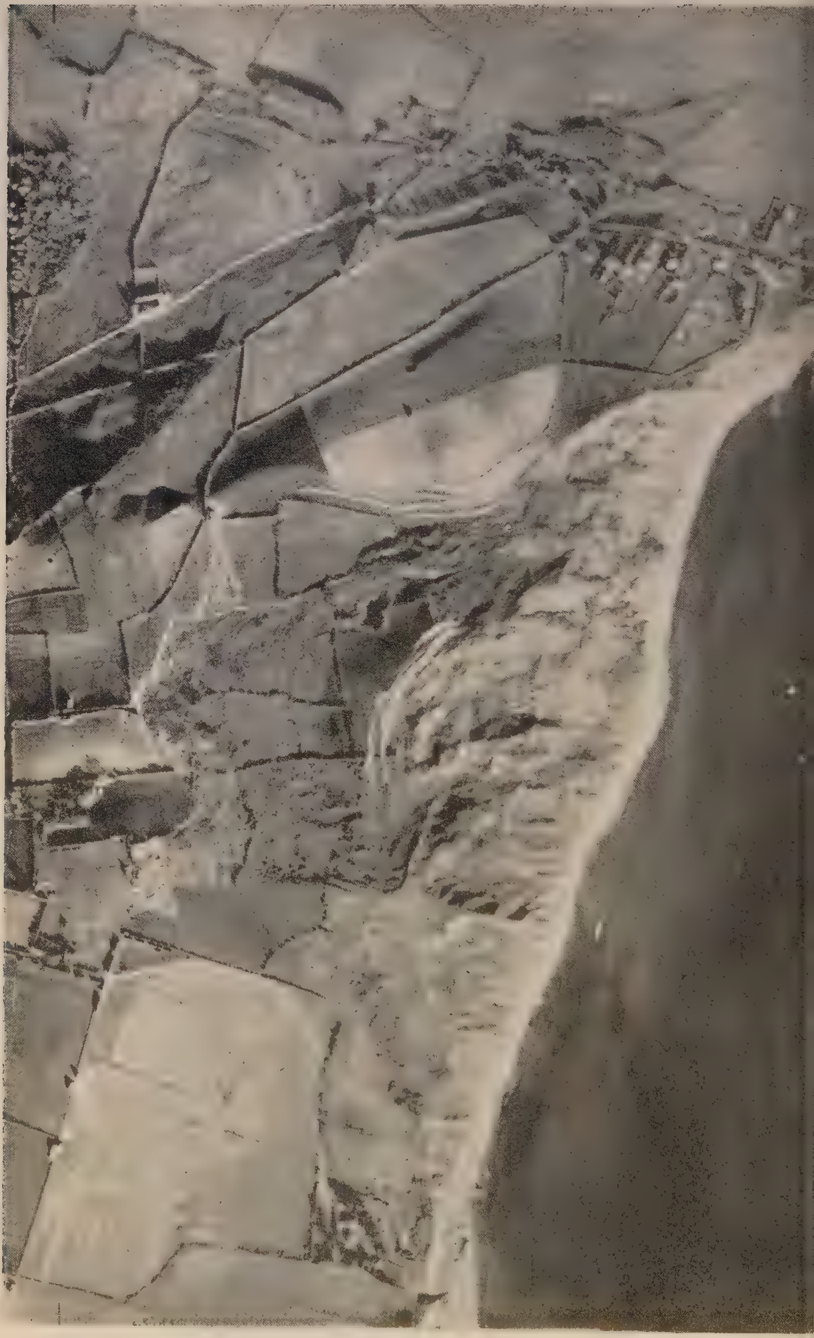
Another (smaller) fault at Pit Cottage is a possibility, but the structure here is still not fully understood. There is apparently Kimeridge Clay almost to the top of the spur, a trench in what appears to be Portland Sand cementstones at the very top, and Portland Stone or cementstones again, apparently *in situ*, beside the path leading to the cottage from the east, at a much lower level than the Kimeridge Clay.

3. STRUCTURE OF THE CRETACEOUS SYNCLINE

The tip-heap of Gault, thrown out of a soakaway on the west side of the stream north of Osmington Mills, referred to above, led to a complete reinvestigation of the structure of the syncline; for it made it clear that, instead of being shallow as supposed by Strahan, the Spring Bottom Syncline at the west end is deep and the Gault must come down into the bottom of the valley.

Closer examination of the sandstone boulders along the Osmington Mills stream, which had been taken (Arkell and others, 1947, p. 353) for slipped Upper Greensand, showed that they are not Greensand but a local development of cowstones in the Gault, and that they are probably not slipped but being excavated by the stream *in situ*. They have not so far yielded any of the characteristic fossils of the Upper Greensand or of the highly ammonitiferous 'purplish brown ferruginous soft stone band' about six feet above the base of the Gault, described by C. W. Wright (Arkell and others, 1947, pp. 192–3) in the neighbouring mud-slides, and so are probably on an intermediate horizon. As stated by Wright (*op. cit.*, p. 178), in the Dorset Albian, 'About halfway through the stage large grey doggers appear, scattered or in continuous bands'. One of these bands apparently is strongly developed at the Mills.

If, then, the base of the Gault is well below stream level in the Osmington Mills valley, the conspicuous sag in the Chalk on the east side of the valley, marked 'Slipped mass of Chalk' on Strahan's 6-inch map (in the Geological Survey Library) and shown, notwithstanding the chalk pit, on the printed map, Sheet 342, as Upper Greensand, must be also *in situ*. A bomb-crater, a few yards east and slightly south of the pit, showed the top grit of the Upper Greensand. Adjoining this there must run a fault, and its course can in fact be traced across the shoulder of the down to the east, where mustard-coloured sand (Upper Greensand) and Chalk lie side by side (see Figs. 1 and 4).



To face p. 25.]

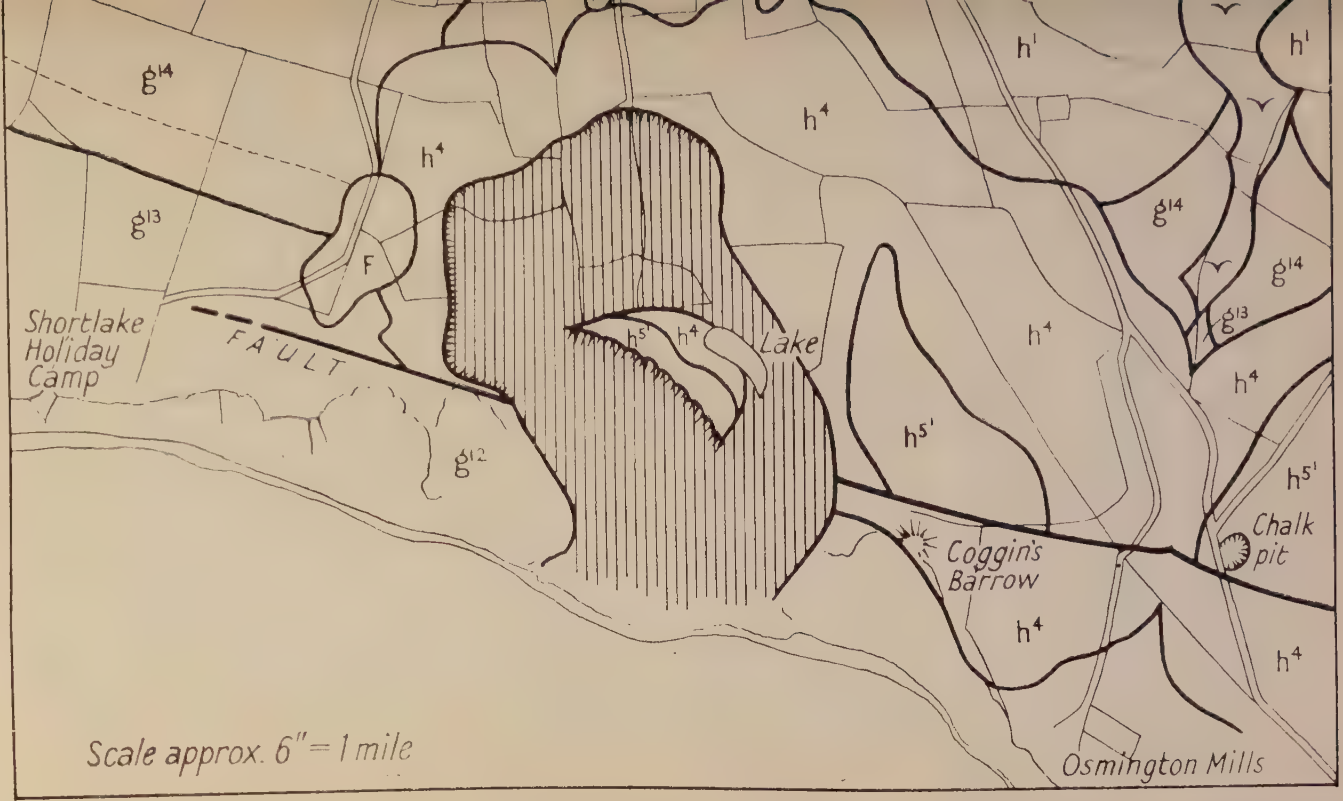


FIG. 2.—Geological map of the area covered by the air photograph (Pl. 2, opposite), showing the landslip and mud-slides (vertical ruling).

Eastwards the fault heads for the north edge of the tufa deposit at Spring Bottom (*op. cit.*, p. 352) and just south of the windpump which raises Ringstead's water-supply, and probably it accounts for both.

This fault, throwing down north, can be picked up on the west side of the valley, where it accounts for the two outliers of Chalk. At Coggin's Barrow the Upper Greensand forms the highest point, and Chalk suddenly comes on to the north, forming lower ground. The true synclinal axis curves from under Spring Bottom Hill south-westwards and passes through the Mills and the mosaic of faults on the foreshore. The Chalk outliers west of the stream belong to the north limb and do not lie in the axis of the syncline as hitherto supposed.

The newly discovered post-Cretaceous Spring Bottom Fault is parallel to and about 300 yards north of the main strike fault in the Jurassic rocks at Osmington Mills, inferred to be of intra-Cretaceous date and to be prolonged eastward to near Holworth House (*op. cit.*, pl. 19). It thus affords yet another example of a post-Cretaceous fault with northward downthrow closely associated with an intra-Cretaceous fault with southward downthrow, the combination so characteristic of South Dorset tectonics.

Whether the steep dips of the west end of Spring Bottom Ridge are continuous with the even steeper part of the syncline near the east end, where the south limb is vertical near Southdown Farm, still remains uncertain. Ringstead chalk pit, by the roadside from Upton to Ringstead (Arkell, 1949), shows Lower Chalk with Plenus Marl at top and Upper Greensand below, dipping only between 8° and 12° about north-north-west, and this is confirmed by the mapping of the Upper Greensand between the road valley and Spring Bottom, between which the top grit crops out through the turf in several places. Moreover, assuming that the main springs of Spring Bottom are given off at the top of the Gault, the dip there cannot be steep. But only boring could reveal whether a belt of steeper dips runs through the centre of the hill.

North and north-west of Southdown Farm, the road-cutting and adjacent pit in the coombe side below, show the junction of Upper Greensand and Chalk standing vertical (Arkell and others, p. 285, and fig. 59, p. 270; Hudleston in 1898 estimated the dip here at 70° north). Recent excavations at the back of a shed in the old pit showed that the Lower Chalk is indurated and heavily slickensided. These exposures are close to the synclinal axis.

East of Southdown Farm the structure is soon lost in the chalk downs, where all the old pits are overgrown and the intervening ground is blanketed by Angular Flint Gravel and flinty hillwash; but the Gault and Greensand and Lower Chalk outcrops at West Chaldon still dip smartly south and show, in diagrammatic fashion, the north limb of the Spring Bottom syncline, of which the axis runs somewhere south of the Winfrith Brook on the south side of High Chaldon. The gradual dying out of the syncline eastward in Chaldon Downs is shown by the structural contour map of the top of the Middle Chalk, prepared by geologists of the D'Arcy Exploration Co. (*op. cit.*, fig. 62, p. 280). Farther west, however, that map unfortunately gives a misleading picture of the structure of Spring Bottom Ridge: in the first place, through a draughtsman's error, it shows the deepest part of the syncline as an anticline,[1] and in the second place it suggests that the syncline takes a north-westward turn west of Osmington Mills, whereas this appearance is, in reality, due to interference with the outcrops by the post-Cretaceous fault described above, which at that time had not been detected, and to oblique truncation by the cliff.

4. ORIGIN OF THE OSMINGTON MUD-SLIDES

The accompanying map differs from that shown in plate 19 in the memoir in the removal of the supposed landslips along the Osmington Mills valley, and in the inclusion of the principal cliff-slides with landslips. Cliff-slides were not marked on pl. 19 and were ignored in the revision, as in the original survey, of Sheet 342. But the mud-slides between Osmington Mills and Black Head provide a complete transition from cliff-slides to inland landslips and are of themselves of such great interest that it seems desirable to indicate them on the new map (see Pl. 2, and Figs. 2 and 4).

The glacier-like triple mud flows between Osmington Mills and Black Head, which are the largest and most remarkable features of their kind on the British coasts, originated, according to local recollections, one night in early spring between 1910 and 1914. They are neither shown on the 1904 edition of the Geological Survey maps nor are they mentioned in the Memoir of 1898. On 22 April 1889, the Geologists' Association walked along the shore from Osmington Mills to Bowleaze, and the description of the walk (Hudleston, 1891) gives no suggestion of anything unusual in the cliffs and does not mention slips. They must be due to some special combination of geological factors, but what those are is not at first apparent, since the Kimeridge shales, which form nearly the whole cliff, dip uniformly landwards and are based on a firm foundation of landward-dipping Corallian limestones. No such slipping has occurred in Purbeck where the Kimeridge shales are horizontal or even tilted slightly seaward, although some of the cliffs are much higher and have no limestone base but a heavy capping of Portland Sand and Stone (*e.g.* Hounstout, which rises to 500 feet almost straight from the sea; whereas Black Head is under 300 feet high).

The explanation is now afforded by the newly detected Spring

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[1] I am indebted to Mr. Brian H. Mottram for pointing out this error: the middle of the three concentric elliptical closed contours shown in the Spring Bottom ridge should be labelled + 300 instead of + 500 and should not have been thickened.

Bottom Fault, which runs parallel and close to the shore through the mud-slides. The fault throws down north and so brings down south-dipping Gault and Greensand against the north-dipping Kimeridge Clay. There is thus an elongated trough (fault-syncline) just inland of the coast and pitching east, from Shortlake to Osmington Mills. The Upper Greensand and Gault are much more porous than the Kimeridge Clay and would have become saturated with water held up against the south fault-wall of impervious Kimeridge Clay.

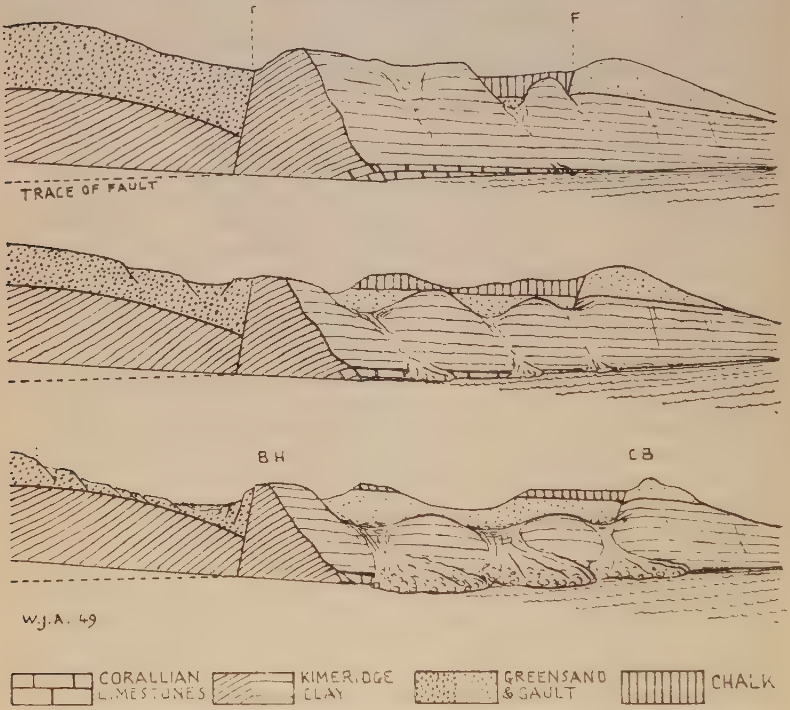

FIG. 3.—Block diagrams illustrating the mode of formation of the mud-slides west of Osmington Mills. BH = Black Head, CB = Coggins Barrow, F = Spring Bottom Fault.

Directly the sea advanced to the point where the south wall was broken through, the saturated south-dipping Gault and Greensand burst out like lava from the side of a shattered volcano. Break-throughs occurred at three points close together (Fig. 3). They were doubtless caused by the erosion of ordinary gullies in the cliff. The undermined land has subsided in all directions, fanwise, to remarkable distances from the points of outlet; but it is significant that the direction of greatest spread of the slipping is north-westwards and westwards. This shows that the spreading of the slips is controlled by the eastward pitch of the fault-syncline. So also does the fact that the Kimeridge Clay in the cliffs of Black Head has not slipped, but that the Gault faulted against it is slipping northwards (*i.e.* inland) and then flowing eastward (parallel to the coast and the fault) until it reaches the nearest outlet southward onto the beach.

5. RELATION OF THE ANGULAR FLINT GRAVEL TO CLAY-WITH-FLINTS

Clay-with-Flints, the normal covering of the high Chalk downs in southern England, occurs in force in north Dorset along the escarpment from Cranborne Chase (Ringwood Sheet, 314) to the ridges north of Maiden Newton (Bridport Sheet, 327), but on lower ground it is sparingly represented east of the River Cerne and dies out east of the Piddle (Dorchester Sheet, 328).

Near the coast, on the Lulworth and Ringstead Chalk and on the crest of the Purbeck Hills, the Survey maps (Sheets 342, 343) show no Clay-with-Flints, but in places where this formation would be expected, blanketing the highest ridges and plateaux, is Angular Flint Gravel—a random mass of smashed flints with little matrix.

Closer examination of the ground in the area of the present map has revealed the presence of Clay-with-Flints alongside the more obvious Angular Flint Gravel, and has provided the key to the relationships of the two deposits.

On the narrow Spring Bottom Ridge, as on the ridge of the Purbeck Hills, all is Angular Flint Gravel. Farther east, however, where the ridge broadens into a plateau with a slightly concave top, Clay-with-Flints takes the place of the gravel. It is even an exceptionally clayey variety. Just before the outbreak of war, in August 1939, excavations on this plateau showed up to 5 feet of red and white mottled clay, with flints so subordinate that I inferred an outlier of Reading Beds caught in the axial region of the Spring Bottom Syncline (Arkell and others, 1947, p. 324 and pl. 19, where 'Loam' is marked across the area in question, on account of the soil). Probably, however, there is no solid formation younger than Middle Chalk in this part of the syncline.

Mapping of the two deposits at first suggests that they are sequential, for it shows the Angular Flint Gravel cropping out on the hill brows and ringing round the Clay-with-Flints, which occupies the flat or concave plateau top. On the other hand, excavations in Angular Flint Gravel, and sections of solution pipes on White Nothe, show that under the weathered and whitened surface layer there is sometimes a good deal of brown clayey matrix. The only places where loamy soil overlies white flint gravel, and where the sequence white flint gravel overlain by Clay-with-Flints is suggested (as, *e.g.* by excavations in a deep ditch north-east of Falcon Barn), are on relatively low ground, and the loam is believed to be recent downwash.

The conclusion to which the evidence leads is that Angular Flint Gravel is a leached residue of Clay-with-Flints. Its distribution, along the narrow ridges and ringing round the Clay-with-Flints of the plateaux, is due to the more rapid run-off of surface water in those situations. The frayed edges of the Clay-with-Flints on the hill brows become converted into Angular Flint Gravel through the washing away of the clay.

There are parallels on some narrow erosion ridges in north Dorset. For instance on the Cowdown to Ridge Hill spur (all above the 700-foot contour), about midway between Cerne Abbas and Sydling St. Nicholas, the deposit marked on the map as Clay-with-Flints consists of typical Angular Flint Gravel. Some old chalk pits show that it is not more than three or four feet thick. Rapid run-off in such situations is a sufficient explanation of the removal of the clay and sand matrix, but in the windy coastal regions a contributory factor may have been absence of forest covering.

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THE STRATIGRAPHY OF THE CHALK OF SUSSEX

PART IV. EAST CENTRAL AREA—BETWEEN THE VALLEY OF THE ADUR AND SEAFORD, WITH ZONAL MAP

By CHRISTOPHER T. A. GASTER, F.G.S.

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PAGE
1. INTRODUCTION 31
2. GEOLOGICAL STRUCTURE 32
3. LIST OF PITS AND SECTIONS 38
ACKNOWLEDGMENTS 64
REFERENCES 64

SUMMARY.—The paper records the results of a zonal survey of the Chalk in the area between the valley of the Adur and Seaford. It reveals some new and interesting facts relating to the geological structure of the area. For instance, the previously described anticline of Kingston near Lewes is found to comprise three folds, *i.e.* (a) Kingston Anticline, (b) Hollingbury Anticline, and (c) Beddingham Anticline. The Kingston Anticline is limited to the area between Mount Caburn and Newmarket Plantation. Faulting is associated with these folds. The Beddingham Anticline extends eastward beyond the district. Other folding, both synclinal and anticlinal, with faulting, are also described. The form of the outstanding valley, known as the Coombe, East of Lewes, is explained. The results are supported by considerable field evidence.

1. INTRODUCTION

THIS paper is the final part of an extensive survey of the Chalk of Sussex. It records the result of a survey of the Chalk in an area west to east of sixteen miles extending from Edburton and Southwick eastward to Firle Beacon and Seaford, and comprises the whole of the Chalk outcrop between that included in Part I [**4**] and Part II [**5**]. The width of the outcrop ranges from three miles at the western end to a little over seven miles at the eastern end. It includes the Chalk outcrop shown on the eastern portion of Sheet 318 (Brighton), the Rottingdean area of Sheet 333, Sheet 319 (Lewes), and the western portion of Sheet 334 (Eastbourne) of the Geological Survey. The three major divisions of Lower, Middle and Upper Chalk shown on those Sheets are replaced in the present work by detailed zonal results as recorded on the accompanying map (Pl. 3, facing p. 64).

In contrast to Western Sussex [**6**], which is a purely rural area, this is much more built over, especially in the coastal region. It includes the towns of Lewes, Brighton, Hove, Newhaven and Seaford. The south is bounded by the English Channel, with chalk cliffs between Black Rock, Brighton, and Newhaven, and the western end of Seaford Head. It also includes the eastern part of the coastal plain between Southwick and Brighton. As it was clear there would be greater difficulty in obtaining the necessary evidence from this area, the author decided to make the present work the concluding part. The Downs were requisitioned for military operations during the last war and were then inaccessible. This delay was not without considerable advantage, as some of the most important evidence has been obtained from various temporary excavations for war purposes, and also from bomb-craters. Large areas of the Downs are now under cultivation, or used for cattle grazing, and are therefore not so accessible as in former days.

The topography is largely determined by the geological structure, and by the strike and dip outcrops of the various hard bands in the Chalk. The greater part of the main escarpment area at the summit ranges from 600–700 ft. O.D., the highest point being Ditchling Beacon (813 ft.). This escarpment, for structural reasons, follows two distinct courses: (1) from Firle Beacon (718 ft.) to Beddingham; here, breached by the valley of the river Ouse, it continues west of Kingston near Lewes to Cold Coombes, and (2) from the Cliffe Hill and Malling Hill, East of Lewes (then breached by the river) follows a west by north direction from Offham, to Plumpton, Ditchling and Wolstonbury Hill, where, after an abrupt change to a southerly direction, it continues westward to Edburton.

The feature referred to as the secondary escarpment [6, 174] is again illustrated on the accompanying map. Owing to the geological structure this also follows two courses indicated by the Marsupites Chalk outcrop, (1) between Southwick and Patcham, Stanmer Park and Falmer to Long Hill, and (2) in the coastal area between Brighton and Seaford.

The form of the outstanding valley, known as the Coombe, east of Lewes, is explained by the westward pitch and southward dip reducing the Chalk outcrop in the zone of *Terebratulina lata*, and bringing in the harder chalk of the succeeding zone of *Holaster planus*. The base of this latter zone, at the east end of the Coombe, is at 300 ft. O.D. The pitch and dip reduces the width as it brings the base of this zone at the mouth to 150 ft. O.D. on the north side and to 100 ft. O.D. on the south side. The base of this zone, which comes in at the top of the Chalk pit at the Prince of Wales Inn, Malling Street, Lewes, 150 yards north of the mouth of the Coombe, shows the local dip of 5° continues between that pit and the Undercliffe section (No. 160 on p. 47) and proves the non-existence of the fault described by Mantell [**10**, 351–3].

2. GEOLOGICAL STRUCTURE

The zoning of the Chalk has revealed some new and interesting facts relating to the geological structure of this area as was also the case in that adjoining to the east [**5**, 511, 512]. The area of Chalk outcrop in east Sussex has been much more folded, and further complicated by faulting associated with the folding, than is the case in west

Sussex. Consequently, the prevailing SSW. inclination of 3°–5° varies considerably both in direction and amount of dip.

Beginning in the north-west, there is a dip fault at Edburton, west of the Church, with the downthrow on the west side.

Henfield Syncline. The axis of this syncline runs eastward near Woodmancote to the Chalk Downs at Wolstonbury Hill [**13,** 6].

Pyecombe Anticline. East of Oreham Common the axial line runs into the Chalk at Pyecombe Gap [**13,** 6] on the western side of Wolstonbury Hill and pitches out on the eastern side of the hill, shown on the accompanying map (Pl. 3) by the outlier of Cortestudinarium Chalk. The secondary or branch flexure at the re-entrant angle of the Chalk escarpment at Saddlescombe, mentioned by Osborne White [**13,** 6], is non-existent, but there is instead a sharp change in the strike here, giving a dip to the SSE. of 3° which continues to Patcham on the north side of the axial line of the 'Mount Caburn' syncline and then to Stanmer Park where, in the Tenant Lain area, the dip increases to 5° and veers SE. by S. The SSE. dip brings in Chalk of the Marsupites Zone at 600 ft. O.D. west of Piddingworth, and a small outlier of similar Chalk at the south end of the 500-foot contour, one-third mile NNE. of Mary Farm, Falmer. The outcrop of the zone three-quarters of a mile to the east of this outlier, which also comes in at the 500-foot contour, indicates a dip in a S. by W. direction, and continues towards Lewes.

No evidence could be found of a fault in the Chalk south of Newtimber, mentioned by Osborne White [**13,** 8].

The Syncline of 'Mount Caburn' [**13,** 6, and **14,** 6]. Zoning of the Chalk has proved that the axial line of this syncline pursues a course, different in many respects from that already recorded. Following a westward pitch of the strata, this syncline enters the area at Oxteddle Bottom, two-thirds of a mile NNW. of Mount Caburn Camp, and, after crossing the northern part of the Caburn outlier of Planus Chalk, the axial line continues westward between the South Street and Southerham pits as recorded [**14,** 6] and then by Lewes Railway Station, Southover, Ashcombe and Long Hill to Housedean, where a strike fault shifts the axis as shown by the outlier of Quadratus Chalk by Ridge Road, quarter-mile north of Falmer Church. This broken axial line continues to the SW. end of Stanmer Park, through the north end of Marquee Brow and south of Great Wood to the fault at Colddean. West of this fault the axis follows its original course, crossing the Brighton–Ditchling Road at spot-level 481, half a mile north of Hollingbury Castle (Camp) [**13,** 7] and terminates at Patcham, where there is a small outlier of Uintacrinus Chalk, one-third mile SSE. of the Church. The westward pitch east of Lewes is not continued west of the River Ouse, and is not present in the southern limb of the syncline between Caburn Bottom and Southerham.

The Anticline of Kingston near Lewes [**13**, 7 and **14**, 7]. Zonal evidence has confirmed that three folds are actually contained in the previous descriptions of this fold, the Kingston anticline being limited to the area between Mount Caburn and Newmarket Plantation. The other two folds, which will be described under separate headings, are the Hollingbury anticline and the Beddingham anticline.

The Kingston anticline is an almost east to west flexure with the axial line running west by south from Mount Caburn where the westward pitch of the strata from the east is terminated by a fault. This fault (the Caburn fault), which determines the eastern end of the Kingston anticline, was discovered largely by evidence obtained from temporary excavations arising out of military operations. It was found that the downthrow was produced by a westerly pitch from the east, there being no pitch on the west side of the fault and the anticline having no pitch along its course. There is a small inlier of the zone of *Terebratulina lata* on the northern limb in Caburn Bottom. Outliers of the zones of *Holaster planus*, *Micraster cortestudinarium* and *M. coranguinum*, shown on the northern limb of the anticline and on the downthrow side of the fault, indicate the displacement of the beds. The axial line of the Kingston anticline commences on the southern slope of Mount Caburn where the base of the zone of *Inoceramus labiatus* outcrops at 240 ft. O.D., and continues its course westward just south of the Upper Rise in the northern part of the large inlier of Gault and Upper Greensand to the smaller inlier of Upper Greensand at Kingston, near Lewes, and then along the foot of the escarpment area, where there are two inliers of Subglobosus Chalk, and finally to the northern end of Newmarket Plantation where the junction of the zones of *Holaster planus* and *Terebratulina lata* reaches the 425-foot contour. It then merges into the northern limb of the Hollingbury anticline in the valley on the west side of the Plantation, where a small inlier of Chalk of the Terebratulina lata Zone is present.

Hollingbury Anticline. This anticline branches from the Kingston anticline at the hill west of Kingston Church and its WSW. axis follows the old Juggs's Road to Newmarket Hill. The axial line then turns in a WNW. direction to Falmer Hill across the Colddean and Lower Bevendean inlier and terminates at Hollingbury, where an inlier of Chalk of the Micraster cortestudinarium Zone is present on the north-west slope. That portion of the anticline which follows the Kingston anticline is divided between the two by a short trough. This has been proved by zonal evidence in the Newmarket Plantation and Cold Coombes area, where the Chalk dips southward from Newmarket Plantation into Cold Coombes and rises again, with a northward dip, to Juggs's Road on the crest of the escarpment. The trough terminates with the Kingston anticline on the west side of Newmarket Plantation.

Associated with these two folds is an important fault in Loose Bottom west of the Kingston anticline. The downthrow on the west side brings the zone of *Offaster pilula* against an outcrop of the zones of *Micraster cortestudinarium* and *M. coranguinum*.

The Colddean fault, already mentioned in connection with the 'Mount Caburn' syncline, has displaced the inliers of Chalk of the zones of *Holaster planus* and *Micraster cortestudinarium* on the east side. These latter, together with that of *Terebratulina lata*, outcrop again in the Colddean and Lower Bevendean inlier on the west side of the fault.

The anticlinal folds of Kingston, near Lewes, and Hollingbury are of the asymmetrical type with dips on the northern limbs ranging up to 20°.

Glynde Syncline. Between these two folds described above and the Beddingham anticline is a shallow trough—the Glynde syncline. Its course through the Chalk is by Glynde Railway Station westward to the Lower Rise where there is a small outlier of Chalk of the Schloenbachia varians Zone in the centre of the Gault–Upper Greensand inlier. It continues by Swanborough, through Castle Hill into Lower Bevendean, and terminates at Moulsecoomb. The synclinal disposition of the Weald Clay between Hailsham and Horse Eye [**14**, 6] may be the eastward extension of this syncline.

The Beddingham Anticline. The evidence of Chloritic Marl south of Peaklet and south of Tilton [**5**, 515, item 1] on the south limb of this anticline, indicates that this fold, with a westward pitch, is a continuation of the fold which runs from Selmeston east-south-eastward by Hankham and Chilley [**14**, 7]. Westward the axial line follows the course shown by the two inliers of Upper Greensand from West Firle to Beddingham, and then it passes by the spot where Glynde Reach joins the main river at Sound Bridge in the south end of the Gault–Upper Greensand inlier. It then continues through Iford and south-westward to the Balsdean area where two small inliers of Labiatus Chalk are indicated. It afterwards continues along Bullock Hill into Lower Bevendean, terminating with a fault at the Lewes Road, Brighton. The westward pitch of this fold weakens at West Firle and Beddingham, where it is slight, and is not continued west of the river Ouse. It will be noticed that this anticline includes the East Brighton portion of the Brighton anticline recorded in 1929 [**3**, 328].

The Lewes Road (Brighton) fault extends from Moulsecoomb southward along the Lewes Road to Grand Parade. It may continue to the seafront near the Palace Pier. The downthrow side of this fault terminates the Brighton anticline, the axial line of which runs in a WSW. direction by the Clock Tower and out to sea west of the West Pier. The evidence now shows that the fold has no pitch [**3**, 328]. The Hove syncline associated with this fold follows a course also from the west side of the Lewes Road fault by Preston Circus, Brighton, to

St. Ann's Well Gardens, Hove, then by Holland Road (indicated by Eocene clay in a temporary excavation at the north end of the Baptist Church) and St. John's Church to Kingsway, where it finally runs out to sea. At Kingsway temporary excavations for the foundations of the King Alfred buildings yielded Quadratus Chalk.

Friar's Bay (Newhaven) Anticline. Evidence of this flexure has been recorded by Rowe [**11,** 337–8] and by Brydone [**1,** 360–1], on the reefs and in the cliffs at Friars Bay, west of Newhaven Harbour. The flexure is also indicated by the presence of Marsupites Chalk at Meeching Quarry [3, 335, item 141]. Further evidence shows that the axis is just north of the quarry. There are no indications that this fold extends east of Newhaven Harbour, where the SSW. dip of the Chalk on that side of the harbour continues to the seafront south of Hawth Hill [**3,** 336–7, item 136, and 338, items 137, 138] causing a dip fault in the harbour area.

The Telscombe Syncline recorded at Telscombe Cliffs by Brydone [**1,** 361] extends eastward to Newhaven (south of the church), terminating at the harbour.

Castle Hill Syncline and Seaford Syncline [**1,** 361]. The SSW. dip east of Newhaven Harbour, already mentioned, continues to the north side of the axial line of the syncline at Seaford. The W. by S. axis of this syncline runs from Chynton farm westward out to sea at Seaford Bay. It may be that the so-called Castle Hill syncline is the termination of the Seaford syncline, the axial line having veered in that direction. There is a small outlier of Quadratus Chalk at the top of the cliff, a little west of Castle Hill. Westward from Old Nore Point, west of Newhaven Harbour, the suggested structure south of the Telscombe syncline is anticlinal.

The Seaford Head Anticline adjoining this area is mentioned in Part II of this work [5, 511].

Rottingdean Syncline and Saltdean Anticline [**1,** 361]. There is no evidence of the existence of this structure, the features in the chalk cliffs being due to the direction of strike differing from that of the coast line.

The Colddean and Lower Bevendean Inlier. This inlier, previously recorded as two inliers [**13,** 40], comprises the outcrop of Chalk of the zones of *Terebratulina lata*, *Holaster planus* and *Micraster cortestudinarium*. It is broken at the north end by the Colddean fault and at the south end by the Lewes Road fault. It will be noticed that there is no inlier of the zone of *Inoceramus labiatus* (*R. cuvieri*) as suggested by W. McPherson [**13,** 40].

Balsdean Inlier [**13,** 42]. This is found to be a much larger inlier than was originally thought. It extends into the valleys on either side of Castle Hill and contains two small inliers of Labiatus Chalk (brought up by the Beddingham anticline) with an inlier of Lata Chalk.

The classification and general description of the various zones of the Chalk recognised in Sussex are contained in Part I of this work [**4**, 359–63]. Further details of the zones of *Offaster pilula* and *Actinocamax quadratus* were published by the author in 1941 [**7**, 210–15].

The zonal mapping of the Chalk in the area has been accomplished on palaeontological evidence only, strike and dip being established on this evidence. Examination of the contour lines and the features produced by hard bands in the Chalk were of location value for zoning it.

Attention is drawn to item 52 on page 42 in the zone of *Schloenbachia varians* which yielded *Terebratulina nodulosa* Eth. This is the only exposure from which the fossil has been obtained. Considered in conjunction with the following item (53) it suggests that the fossil here occupies the same position in the zone as in bed No. 4 in Kent [**9**, 40]. Unfortunately the zone is not fully exposed in Sussex, but there are indications that a similar set of beds to those of Kent could be established.

The demarcation between the zone of *Schloenbachia varians* and that of *Holaster subglobosus* has been recorded in the quarry adjoining the railway south of the Fox Inn at Southerham. The upper limit of the zone of *S. varians* yields *Turrilites costatus* Lam., and other fossils with which determination the present author agrees [**14**, 6].

In 1929 [**3**, 331, item 118] the author recorded large ammonites in the highest part of the quarry at the Chalk Works, south-east of the Railway Station, Glynde. This is about 80 ft. above the base of the zone of *Holaster subglobosus*. The author has seen a similar seam of these ammonites in the same position in the zone near Beachy Head on the well-developed wave cut platform of chalk at the base of the Cliffs showing dip and strike joints in plan [**2**, 75].

The late Mr. Frank Newington of Newington and Co., the owners of the Glynde Chalk Works, told the author that when the men, working from the top of the quarry, reached chalk yielding *Turrilites* they found that below this horizon the chalk became useless for commercial purposes. This suggests that the bed with *Turrilites* is the upper limit of the Varians Zone which is exposed near the quarry floor [**3**, item 118 on p. 330].

Trochiliopora gasteri Thomas (**12**, 527–29] has again proved useful in determining the base line of the Coranguinum Zone, the upper boundary of the Trochiliopora Bed being about 27 ft. above the base of the zone. Included in the basement beds are the yellow nodular bands mentioned by A. W. Rowe [**11**, 329]. Among some of the features containing these hard bands of chalk are Ditchling Beacon, Plumpton Plain, downthrow side of the fault at Mount Caburn, Firle Beacon, Newmarket Hill, and Hollingbury. The chalk above the Trochiliopora Bed is typical of the Coranguinum Zone in nature.

The author throughout this work has accepted the limits assigned to the zone of *Micraster cortestudinarium* by A. W. Rowe [**11**, 327, 328]. He has been unable to agree with Griffith and Brydone's [**8**, 9] inclusion in the zone of the lower fourth of the Coranguinum Zone of Rowe (*i.e.* chalk yielding *Micraster cortestudinarium* and *M. praecursor*). This would serve no useful purpose and lead to unreliable zoning of inland sections. Griffith and Brydone admit they "have included the beds in question, where identifiable in Hants, which is rarely the case, in the *Micraster cortestudinarium* zone".

The special stem of *Bourgueticrinus* ornamented with a series of small tubercles, found in the Uintacrinus Subzone [**5**, 514], has again proved a useful guide to the subzone.

Fortunately, owing to the large amount of evidence obtained, it has enabled the author to estimate with considerable accuracy the thickness of each zone in the area, and the following results have been established:[1]

		Feet.	
Senonian	Zone of *Actinocamax quadratus*	100	(incomplete)
	Zone of *Offaster pilula*	165	
	(a) Subzone of *Echinocorys scutatus* var. *cincta* (105 ft. thick)		
	(b) Subzone of *Echinocorys scutatus* var. *depressa* (60 ft. thick)		
	Zone of *Marsupites testudinarius*	100	
	(a) Marsupites Subzone (50 ft. thick)		
	(b) Uintacrinus Subzone (50 ft. thick)		
	Zone of *Micraster coranguinum*	230	
	Zone of *Micraster cortestudinarium*	100	
	Zone of *Holaster planus*	55	
Turonian	Zone of *Terebratulina lata*	130 to 140	
	Zone of *Inoceramus labiatus* (including Melbourn Rock at base)	100	
Cenomanian	Zone of *Holaster subglobosus* (including the marls with *Actinocamax plenus* at top of zone)	120	
	Zone of *Schloenbachia varians* (including Chloritic Marl at base of zone)	80	
		1190	

The thickness of 80 ft. assigned to the zone of *Schloenbachia varians* is the same as that in the adjoining eastern area [**5**, 514]. The thickness of 100 ft. for the zone of *Actinocamax quadratus* is represented in the Downs area. No account is taken of any newer chalk of the zone which may exist in the Coastal Plain area south of the Downs.

3. LIST OF PITS AND SECTIONS[2]

In 1929 the author recorded a list of pits and sections in this area, which is supplemental to the detailed list in this paper. It has been found necessary, on further evidence, to make observations on the following three items in the 1929 list [**3**, 330–8].

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[1] A table of fossils from the various zones was published in 1929 [3, 339 and Table].

[2] The fossils collected by the author from these localities have been presented to the Trustees of the British Museum (Natural History).

(a) *Item* 127, p. 330. The section in the meadow on the west side of the high road, NW. of entrance to main Cement Works at Asham, Beddingham, yielding *Turrilites costatus* Lam., represents the upper limit of the zone of *Schloenbachia varians*.

(b) *Item* 67, p. 331. Railway cutting due south of Colddean. Further evidence shows that this section is in the zone of *Terebratulina lata*, with a capping of the zone of *Holaster planus*. Therefore, no outcrop of the zone of *Inoceramus labiatus* is present here.

(c) *Item* 80, p. 336. Temporary section in Vernon Avenue, NE. of site of Warren Farm Schools Well, Woodingdean. It is found that this exposure should be transferred to the zone of *Micraster coranguinum*. A temporary section by the wall at the south end of the Schools at the 400-foot contour yielded fossils indicating the Chalk to be of the upper part of the zone of *Micraster coranguinum* and 500 yards SE. of the Schools, also at 400 ft. O.D., the Chalk yielded *Uintacrinus* ossicles in the base of the Marsupites Zone. It is therefore rather difficult to accept either figure of 460 ft. or 418 ft. of 'chalk-with-flints' recorded for the Warren Farm Well. The evidence suggests about 350 ft. as the thickness of 'chalk-with-flints' at this well. The SSW. dip there is 5°.

Owing to the geological structure now disclosed, it was necessary to obtain a larger amount of evidence than was at first anticipated: 496 items (pits and sections) are enumerated below, and further items, used in the preparation of this work, have been excluded. All the localities listed have been zoned by the author. Chalk thrown out by burrowing animals has again been utilised.

The following editions of the Six-inch Sheets of the Ordnance Survey were used in the preparation of the zonal map, and also for the descriptions of the evidence, reference to the Sheet on which the evidence is included being indicated against each item:

Edition of 1911: Sheets 54 SE., 54 NW., 67 NE., 68 SW., 77 NE., 79 NW., 79 SW.
,, ,, 1912: Sheets 52 NE., 53 SE., 53 NE., 53 NW.
,, ,, 1914: Sheet 52 SW.
,, ,, 1928: Sheet 78 NW.
,, ,, 1929: Sheets 68 NW., 78 NE.
,, ,, 1930: Sheet 54 SW.
,, ,, 1931: Sheets 66 NE., 67 SW., 65 NW.
,, ,, 1932: Sheets 67 SE., 52 SE., 66 SW.
,, ,, 1933: Sheet 65 NE.
Provisional Edition (Revision of 1929 with additions in 1938): Sheets 66 NW., 67 NW.
Provisional Edition (Revision of 1928–9 with additions in 1938): Sheet 66 SE.
Provisional Edition (Revision of 1929–30 with additions in 1938): Sheet 53 SW.

ZONE OF *SCHLOENBACHIA VARIANS*

Chloritic Marl

1. In road bank on west side of cottage at B.M. 137.4, 200 yards west of Edburton Church. 52 SW
2. At 200 ft. O.D., in road bank, 100 yards SW. of Poynings Church, also in road bank on west side near 220 ft. O.D., 100 yards NW. of church. 52 NE.
3. By boundary hedge, 40 yards north of main road and half-mile NNE. of Poynings Church. 52 NE.
4. Digging for post by hedge, 60 yards west of Church Lane at spot-level 243, 500 yards SW. of Newtimber Church. 52 NE.
5. West bank of pond at Redhouse Farm, Newtimber. 52 NE.
6. Above 200 ft. O.D., on west side of hedge, 300 yards ESE. of Foxhole Cottages and 500 yards SW. of Little Danny, Hurstpierpoint. 52 NE.
7. At 200 ft. O.D., temporary excavation in lane near fish pond, 100 yards ENE. of the Rectory, Clayton. 53 NW.
8. In temporary excavation on east side of road near B.M. 267.9, east of south end of Crossgoats Shaw, 200 yards SE. of Parkbarn Farm, Ditchling. 53 NW.
9. At 250–60 ft. O.D., temporary excavation by footpath at SW. end of Westmeston Place, Westmeston. 53 NE.
10. In bank of lane just below 200 ft. O.D., immediately north of overgrown pit (Chalk Marl), 300 yards south of Warningore Farm, Chailey (Det. No. 2). 53 NE.
11. At 100 ft. O.D., in railway cutting, half-mile SE. of Cooksbridge Station. 54 NW.
12. Above 100 ft. O.D., bank above footpath at NW. side of main road, 200 yards NE. of Middleham House, Ringmer. 54 SE.
13. With Chalk marl above in old pit in meadow at 50 ft. O.D., 100 yards NE. of Oldhouse Farm and half-mile north-east of Glyndebourne, Ringmer. *S. varians* Sow. 54 SE.
14. At parish boundary, 200 yards SSW. of Peaklet, quarter-mile south of Charleston, West Firle. 68 NW.
15. At spring, 250 yards east of Beanstalk, west of Charleston, West Firle. 68 NW.
16. Bank of pond on west side of Heighton Street, Firle Park, near B.M. 76.9, two-thirds mile NE. of West Firle Church. 67 NE.
17. In material from temporary excavation 11 ft. down in cottage garden on east side of Heighton Street, Firle Park, 200 ft. north of B.M. 99.4. 67 NE.
18. In Firle Park, 100 yards west of Heighton St. Clere (site of), West Firle. 67 NE.
19. In west bank of lane to Firle Bostal at 100 ft. O.D., 250 yards south of School, West Firle. 67 NE.
20. In bank of pond at corner of field, 100 yards NW. of Preston Court house, Beddingham. 67 NE.
21. Bank of pond, 50 yards west of track to Narroway buildings—350 yards ESE. of Beddingham Church. 67 NE.
22. Temporary excavation in field above 50 ft. O.D. near east side of main road, 250 yards south of Cobb Place, WSW. of Narroway buildings, Beddingham 67 NE
23. Temporary excavation in garden of house near 60 ft. O.D., on east side of main road, 350 yards south of Cobb Place, Beddingham. 67 NE.
24. At 40 ft. O.D., 100 yards and 300 yards south of Rise Barn, Lower Rise, Southover Without, Lewes. 67 NW.
25. Above the 50-foot contour, in north bank of the Droveway, 200 yards east of the high road, and three-quarter mile east by south of St. Pancras's Church, Kingston near Lewes. Immediately above the Chloritic Marl is a hard seam with *S. varians* Sow. 67 NW.

26. Temporary excavations for fencing by footpath from 50 ft. O.D. to about 75 ft. O.D., 200–300 yards NE. of Carr's Cottage, Kingston near Lewes. 67 NW.
27. In material dug for post at east end of Parish Hall, 150 yards east by north of St. Pancras's Church, Kingston near Lewes. 67 NW.

Chalk Marl

28. Small pit at 200 ft. O.D., 200 yards south of Aburton Farm, SE. of Edburton Church. Fossiliferous Chalk, low in zone. 52 SW.
29. Track below 300 ft. O.D., immediately below chalk pit in zone of *Holaster subglobosus*, quarter-mile south of Perching Manor House (supposed site of), Fulking. Chalk yielded *Plicatula inflata* Sow. and *Turrilites costatus* Lam. Top beds of zone. 52 SE.
30. In road bank at east corner, 50 yards north of Poynings Church. Fossiliferous, near base of zone. 52 NE.
31. Pit on west side of Newtimber Hill at south end of Beggar's Lane, Newtimber. *Scaphites aequalis* Sow. Upper part of pit, above the 300-foot contour, in zone of *Holaster subglobosus* yielded *H. subglobosus* Leske and *Pecten beaveri* Sow. 52 NE.
32. Bed of stream by road near lodge to Newtimber place, quarter-mile north of Newtimber Church. *Pecten orbicularis* Sow. 52 NE.
33. East bank of main road near 200 ft. O.D., east to north-east of lodge to Newtimber Place, quarter to one-third mile NNE. of Newtimber Church, *Schloenbachia varians* Sow., *Rhynchonella mantelliana* Sow., *R. martini* Mant., *R. grasiana* d'Orb., *Kingena lima* Defr., *Micrabacia coronula* Goldf. and *Plicatula inflata* Sow. 52 NE.
34. Upper limit of zone at 220 ft. O.D., in track 200 yards NE. of lodge to Newtimber Place and 200 yards south of Devonshire Villa, Newtimber. *Schloenbachia varians* Sow. and *Turrilites costatus* Lam. 52 NE.
35. Section in bank on west side of Pyecombe Garage, about 80 yards south of B.M. 247.8 at Dale Gate, The Dale, Pyecombe. *Rhynchonella mantelliana* Sow. and *R. martini* Mant. 52 NE.
36. East bank of high road at Dale Hill near B.M. 277.8, about 350 yards west of Pyecombe Post Office. *Micrabacia coronula* Goldf. 52 NE.
37. Bank of track near 300 ft. O.D., 50 yards SE. of B.M. 257.9, quarter-mile NNE. of triangulation spot at Camp on Wolstonbury Hill, Pyecombe. *Rhynchonella mantelliana* Sow. (common). 52 NE.
38. Top beds of zone near 320 ft. O.D., in Middleton track, quarter-mile SSE. of Westmeston Church 53 NE.
39. Temporary excavation in field, south of footpath, 300 yards east of Plumpton Place, Plumpton. *Scaphites aequalis* Sow. 53 NE.
40. Old marl pit at west end of copse, Long Walk, 200 yards ENE. of Hackmans Farm, Plumpton. *Schloenbachia varians* Sow. 53 NE.
41. Bomb-crater in field, 50 yards east of Allington Lane, 200 yards NNW. of Courthouse Farm, St. John Without, Lewes. *S. varians* Sow. 53 NE.
42. East bank of railway, west of Hamsey House, SSE. of Cooksbridge Station, Hamsey. *S. varians* Sow. 54 NW.
43. Railway cutting under bridge, 150 yards NW. of Old Church, Hamsey. *Rhynchonella mantelliana* Sow. 54 SW.
44. Old workings, 100 yards NW. of Malling Gate Cottages, Stoneham, South Malling Without, Lewes. *S. varians* Sow. 54 NW. 54 SW.
45. Top of zone at about 80 ft. O.D., in cultivated field, 350 yards west of Spring Barn, NE. of St. Pancras's Church, Kingston near Lewes. *S. varians* Sow. and *Scaphites aequalis* Sow. 67 NW.
46. Temporary excavation (10 ft. down) in garden for new house, about 70 yards NW. of Vicarage, Iford. *Holaster* sp. and *Plicatula inflata* Sow. Low in zone. 67 NW.

47. Rabbit burrows by hedge, below 50 ft. O.D., at SE. end of field, quarter-mile SE. of Rise Farm, Upper Rise, Southover Without, Lewes. *S. varians* Sow. 67 NW.
48. *S. varians* Sow. obtained from NW. corner of cultivated field on north side of Upper Rise, 150 yards west of buildings at Rise Farm, Southover Without, Lewes. 67 NW.
49. Temporary excavation near 50 ft. O.D., south of cottages, 100 yards SE. of Ranscombe Farm, South Malling Without, Lewes. 67 NE.
50. Chalk pit in meadow on west side of high road at about 50 ft. O.D. about one mile SSW. of Beddingham Church. Junction with Subglobosus Zone in pit. 67 NE.
51. Temporary excavation on north side of main road near spot-level 19; 150 yards NNE. of Beddingham Church. *S. varians* Sow. 67 NE.
52. Road widening at cross-roads at NW. corner near B.M. 34.7, quarter-mile north of Little Dene, Beddingham. *S. varians* Sow., *Rhynchonella mantelliana* Sow. and *Terebratulina nodulosa* Eth. 67 NE.
53. Road widening on south side opposite Toll Gate filling station at B.M. 54.5, 250 yards SSE. of Mill House and nearly half-mile SE. of Glynde Railway Station. *S. varians* Sow., *Rhynchonella mantelliana* Sow. and *Kingena lima* Defr. 67 NE.
54. Two bomb-craters on north side of road at 50 ft. O.D., about 100 yards to the west of last-mentioned item, yielded similar evidence. 67 NE.
55. Section at west end of Comps Shaw, half-mile NE. of Beddingham Church. *S. varians* Sow. 67 NE.
56. Road bank by row of trees above 100 ft. O.D., at triangulation spot, 400 yards south of School, and a little over one-third mile west by north of West Firle Church. Near base of marl. 67 NE.

ZONE OF *HOLASTER SUBGLOBOSUS*

57. Chalk pit, 300–400 ft. O.D., quarter-mile south of Perching Manor House (supposed site of) Fulking. Belemnite Marls in top of pit. 52 SE.
58. Chalk pit, above 300 ft. O.D., immediately south of Dyke Lane, Poynings. Belemnite Marls in top of pit. 52 SE.
59. Small cutting near spring at about 225 ft. O.D., Devil's Dyke, 350 yards west of Saddlescombe Chalk Pit. 52 SE.
60. Roadside chalk pit on west side of North Hill, Newtimber, 250 yards east of Poynings Church. Belemnite Marls in pit, capped by Melbourn Rock at south end, with base of Melbourn Rock in centre of adjoining small pit. 52 NE.
61. Newtimber Lime Works pit, reaching the 400-foot contour, one-third mile NE. of Newtimber Church. Belemnite Marls in upper part of pit capped by Melbourn Rock. 52 NE.
62. Small pit in Crabtree Bottom reaching 350 ft. O.D., half-mile east of Newtimber Church. Belemnite Marls on which Melbourn Rock rests in top of pit. 52 NE.
63. Pit reaching 400 ft. O.D., 250 yards north of Camp on Wolstonbury Hill, Pyecombe. 52 NE.
64. Exposure of zone in bank of track from Slipe Barn to junction of Belemnite Marls with Melbourn Rock, above 400 ft. O.D., 300 yards SE. of Whitelands, Clayton. 53 NW.
65. Bank above field on north side of road, one-third mile SW. of Tulleyswells Farm, St. John Without, Lewes. Basement beds of zone. 54 NW.
66. Old Grey Pit, Southerham, on south side of Machine Bottom, ESE. of Southerham Farm, South Malling Without, Lewes. Belemnite Marls exposed in top north-east end of pit. 54 SW.
67. Chalk near edge of cultivated field, just above 100 ft. O.D., about 50 yards east of triangulation spot, quarter-mile SE. of Southerham Farm, South Malling Without, Lewes. *Holaster subglobosus* Leske. 67 NW.

68. (a) Upper part of field, above 100 ft. O.D., on south side of Mount Caburn, Glynde. *Holaster subglobosus* Leske and *Pecten beaveri* Sow., obtained at 120 ft. O.D., 200 yards WNW. of Brigdens Farm; (b) Chalk in top of field, above 50 ft. O.D., immediately south of high road between Swale Bank West and Swale Bank East and south of Mount Caburn, Glynde. Chalk yielded *Pecten beaveri* Sow., *Nautilus* sp. and *Acanthoceras* sp. (These two items [at about the same position in the zone] are interesting as they indicate a southward dip from (a) to (b), south of the axis of the Kingston anticline). 67 NE.
69. Evidence of upper part of zone in bank on north side of tramway to Caburn Pit, south of highway at Brigdens Hill, Balcombe Link, Glynde. 67 NE.
70. Evidence of basement beds of zone on cultivated land in the north part of the 50-foot contour, 350 yards SW. of Station Farm, Glynde. 67 NE.
71. Temporary section near entrance to burial ground, 50 yards south of Glynde Church. Low in zone. 54 SE.
72. North bank of track (130–40 ft. O.D.), 100 yards west of Glyndebourne Farm, Glynde. Low in zone. 54 SE.
73. Chalk pit near 350 ft. O.D., on east side of Round Hill, 350 yards east of Roundhill Plantation below Firle Beacon, West Firle. Belemnite Marls in upper part of pit capped by Melbourn Rock. 68 NW.
74. Pit at 230–40 ft. O.D., 500 yards SW. of St. Pancras's Church, Kingston near Lewes. 67 NW.
75. Section on west side of Coombe just below the 300-foot contour, one mile NE. of Newmarket Hill and three-quarters mile west by north of St. Pancras's Church, Kingston near Lewes. 66 NE.
76. Bomb-crater in copse near 270 ft. O.D., one-third mile west of Manor House, Kingston near Lewes. 66 NE.
77. Railway siding for Asham Cement Works, Beddingham. Near base of zone. 67 NW.

ZONE OF *INOCERAMUS LABIATUS*

78. Melbourn Rock exposed (with Belemnite Marls below) at 400 ft. O.D., in Bostal, quarter-mile SE. of Shepherd and Dog (P.H.) Fulking. 52 SE.
79. Melbourn Rock just below pit on east side of B.R. at 400 ft. O.D., with chalk yielding abundant *Inoceramus labiatus* Schlot. in pit, one-third mile south of Wickhurst Barns, Poynings. 52 SE.
80. Melbourn Rock just above pit immediately south of Dyke Lane, Poynings. 52 SE.
81. Base of Melbourn Rock at 410 ft. O.D., Cowdown Lane, 250 yards SW. of Pyecombe Post Office. 52 NE.
82. Junction of Belemnite Marls and Melbourn Rock in track about 200 yards south of Warren Farm and about 80 yards north of entrance to chalk pit containing the 400-foot contour on east side of Wolstonbury Hill, Pyecombe. The chalk pit yields *Inoceramus labiatus* Schlot. and *Rhynchonella cuvieri* d'Orb. 52 NE, 53 NW.
83. Chalk of the zone is seen in the workings at the south end of the Clayton Lime Works pit (disused). 53 NW.
84. Junction of Belemnite Marls and Melbourn Rock exposed in small pit 200 yards SE. of Clayton Court Farm, Clayton. 53 NW.
85. Chalk of zone seen in road bank for about 150 yards NW. from Plough Inn, Pyecombe, at and above 300 ft. O.D. 53 NW.
86. Junction of Belemnite Marls and Melbourn Rock in workings by track above 400 ft. O.D., 300 yards SE. of Whitelands, Clayton. 53 NW.
87. Pit, west side of Ditchling Bostall, 200 yards SW. of Wick Farm, Ditchling. Part of pit above 500 ft. O.D. yielded *Inoceramus labiatus* Schlot. and *Rhynchonella cuvieri* d'Orb. 53 NW.
88. Junction of Belemnite Marls and Melbourn Rock in small pit above 400 ft. O.D., east of Ditchling Bostall, quarter-mile ESE. of Wick Farm, Ditchling. 53 NW.

89. Base of Melbourn Rock a few feet above the 400-foot contour in Middleton track, SE. of Westmeston Church. 53 NE.
90. Junction of Belemnite Marls and Melbourn Rock at 400 ft. O.D. exposed in Streat Bostall, one-third mile SE. of Goat Farm, Streat. 53 NE.
91. Small pit with Melbourn Rock near 350 ft. O.D., one-third mile SSW. of Plumpton Place, Plumpton. 53 NE.
92. Quarry marked 'Novington Chalk Pits' on Six-inch Sheet, 350 yards SW. of Novington Farm, Westmeston (Det.). At the parish boundary, below pit and near 350 ft. O.D., is the base of the Melbourn Rock, and the Chalk-with-Marlseam in top of south working of quarry indicates the upper part of the zone. 53 NE.
93. Small pit with Melbourn Rock and Belemnite Marls immediately below at 350 ft. O.D., in Warningore Bostall, quarter-mile SE. of Novington Farm, Chailey (Det. No. 2). 53 NE.
94. Junction of Belemnite Marls and Melbourn Rock in track at 370 ft. O.D. at parish boundary, about 50 yards north of small pit yielding *Inoceramus labiatus* Schlot. and *Rhynchonella cuvieri* d'Orb., nearly half-mile west by north of Courthouse Farm, St. John Without, Lewes. 53 NE.
95. Chalk cutting near 150 ft. O.D., by side of track from Offham Village, to north chalk pit on Offham Hill, 150 yards SSW. of Offham Church. Top beds of zone. 54 SW.
96. Small pit at 100 ft. O.D., 200 yards SSE. of Offham Church. 54 SW.
97. Chalk section at foot of river cliff near 50 ft. O.D., about 100 yards NE. of Chalk Pit Inn, Offham. *Inoceramus labiatus* Schlot. 54 SW.
98. Small pit below 50 ft. O.D. in copse (bank below field), 200 yards NW. of Old Malling Farm and NW. of South Malling Church. Melbourn Rock in pit containing nodules in matrix of marl. *Inoceramus labiatus* Schlot. and *Rhynchonella cuvieri* d'Orb. 54 SW.
99. Small pit at SE. end of Old Malling Farm, NW. of South Malling Church, yielding *Inoceramus labiatus* Schlot. and *Rhynchonella cuvieri* d'Orb. 54 SW.
100. Small pit by barn, 200 yards NW. of South Malling Church, below the 50-foot contour. Strong marl seams in pit. *Galerites subrotundus* Mant. and *Ostrea vesicularis* Lam. Pit in upper part of zone. 54 SW.
101. Melbourn Rock with Belemnite Marls below in temporary excavation in field immediately west of Lewes–Uckfield road, 500 yards SW. of Upper Stoneham Farm and 100 yards NE. of junction with Lewes–Ringmer road, South Malling Without. 54 SW.
102. Junction of Melbourn Rock with Belemnite Marls near 175 ft. O.D., in east bank of track to Bridgwick Pit, 250 yards NE. of pit, South Malling Without. 54 SW.
103. Melbourn Rock at 110 ft. O.D., just above NE. end of the old Grey Pit on south side of Machine Bottom, Southerham; also SE. of this evidence at 140 ft. O.D. and 200 ft. south of tumulus at 'Round the Down', Southerham, South Malling Without. 54 SW.
104. Melbourn Rock in track at 200 ft. O.D. with Labiatus Rock well exposed at 230 ft. O.D., quarter-mile SE. of Southerham (old) Grey Pit, north of Ranscombe Hill, South Malling Without. 67 NW.
105. Melbourn Rock near 220 ft. O.D. immediately above pit [3, 331, item 116] —Belemnite Marls exposed in pit—250 yards north of Ranscombe Farm, South Malling Without, also at the same level 200 yards to the east of pit. 67 NE.
106. Melbourn Rock 35 ft. below field in NW. end of Brigden's Shaw, near 160 ft. O.D., and *Rhynchonella cuvieri* d'Orb. obtained at 50 ft. O.D. at south end of Shaw, East of Brigden's Farm, Glynde. 67 NE.
107. Melbourn Rock exposed at 50 ft. O.D. on north side of high road 100 yards west by south of Convalescent Home, and 300 yards SW. of the Vicarage, Glynde.

108. Evidence of zone by cottage and parish boundary just below the 200-foot contour, 50 yards SE. of New Barn, about two-thirds mile SW. of Goat Farm, Ringmer. 54 SE.
109. Junction of Melbourn Rock and Belemnite Marls at 270 ft. O.D. in Week Lane, quarter-mile WNW. of Glyndebourne, Ringmer. 54 SE.
110. Melbourn Rock at about 190 ft. O.D. in lane to Downs, 350 yards NW. of Glynde Church. 54 SE.
111. Chalk pit below 300 ft. O.D. in Coombe east of Firle Plantation, three-quarters mile SE. of West Firle Church. Melbourn Rock and Labiatus Rock in pit. 67 NE.
112. Chalk yielding *Inoceramus labiatus* Schlot. in bank on south side of main road near spot-level 82, 150 yards SE. of Abergavenny Arms (P.H.), Rodmell. 67 NW.
113. Small pit at the 100-foot contour, 200 yards NW. of Spring Barn, Kingston near Lewes. Junction of Melbourn Rock with Belemnite Marls in pit. Dip, north. 67 NW.
114. Base of Melbourn Rock at 300 ft. O.D. one-third mile SW. of St. Pancras's Church, Kingston near Lewes. Evidence of zone also seen at 310 and 350 ft. O.D. 67 NW.
115. Hard nodular chalk yielding *Inoceramus labiatus* Schlot. above 200 ft. O.D. At Scabby Brow, half-mile NW. of Church, Kingston near Lewes. 66 NE.
116. Base of zone, 330–40 ft. O.D., seen in sides of Juggs's Road, half-mile west of church, Kingston near Lewes. 66 NE.
117. Edge of cultivated field, two-thirds mile SW. of Newmarket Inn, St. Ann Without, Lewes, on north side of parish boundary, just above the 200-foot contour. Hard chalk with *Inoceramus labiatus* Schlot. 66 NE.
118. Edge of cultivated land just below the 200-foot contour, half-mile SSW. of Newmarket Inn, St. Ann Without, Lewes. Hard chalk with *Inoceramus labiatus*, Schlot. Low in zone. 66 NE.
119. Hard chalk yielding *Inoceramus labiatus* Schlot. at 300 ft. O.D. 100 yards NE. of pond in Coombe below, just under one mile west of Church, Kingston near Lewes. 66 NE.
120. Base of Melbourn Rock just below 200 ft. O.D. at edge of cultivated field by copse, three-quarters mile WSW. of Manor House, Iford. 67 NW.
121. Zonal evidence suggests inliers of zone in Falmer Bottom and Balsdean Bottom, NW. and NE. of Norton Farm, East of Woodingdean Brighton. (See map, Pl. 3). 66 NE.
122. Melbourn Rock just above the 400-foot contour on north side of Newtimber Hill, one-third mile SW. of Redhouse Farm, Newtimber. 52 NE.
123. Melbourn Rock just above the 400-foot contour, 40 yards south of Chantry, on west side of Wolstonbury Hill, NW. of Pyecombe Post Office. 52 NE.

ZONE OF *TEREBRATULINA LATA*

124. Upper part of zone (with flints) in chalk dug for electric pylon, near 450 ft. O.D., quarter-mile SSE. of Camp on Edburton Hill, Edburton. 52 SW.
125. Junction of zone with zone of *Holaster planus* in roadside section at 500 ft. O.D., Summer Down 250 yards south of pond at Saddlescombe Farm, Newtimber. 52 SE.
126. Pit on west side of Camp on Wolstonbury Hill, Pyecombe. *Terebratulina lata* Eth. obtained at 600 ft. O.D. in north section, 200 yards west of triangulation spot. Upper half of south workings, above 600 ft. O.D., yielded fossils of the zone of *Holaster planus*. 52 NE.
127. Pit, quarter-mile NW. of Pyecombe Church, and quarter-mile east of Pyecombe Post Office. *Terebratulina lata* Eth. obtained in pit, also in bank above pit. 52 NE., 53 NW.
128. Evidence of zone obtained in Streat Bostall, Streat, between 500 and 600 ft. O.D. Top of zone at 600 ft. O.D. 53 NE.

129. Chalk pit on south side of Warningore Bostall, Chailey (Det. No. 2), reaching 500 ft. O.D. Another pit (with flints at top) immediately south, in upper beds of zone. 53 NE.
130. Chalk section below 300 ft. O.D. on west side of track to north chalk pit on Offham Hill, south of Offham Church. Top of zone at 300 ft. O.D. 54 SW.
131. Chalk pit reaching 400 ft. O.D. at NE. end of Saxon Down, half-mile WSW. of Glyndebourne, Glynde. No flints present. *Terebratulina lata* Eth. obtained. 54 SE.
132. *Terebratulina lata* Eth. obtained from section in bank at east end of field, 100 yards north of pond in Oxteddle Bottom, South Malling Without. 54 SE.
133. The whole of the Rifle Range from the 900 yards range on the south side of Saxon Down, SW. to the south end of Oxteddle Bottom, covers an outcrop of the zone. Evidence of the zone is to be seen on the slopes on either side of the Range. At the targets in Oxteddle Bottom, chalk of the zone of *Holaster planus* is present. 54 SE.
134. *Terebratulina lata* Eth. obtained in bank of track at 300 ft. O.D. above top of B.R., half-mile WSW. of Northease Farm, Iford. Nodular chalk present. 67 NW.
135. Temporary trench at 340 ft. O.D., 200 yards SW. of dew-pond on Bird Brow, one and a half miles WSW. of Iford Church, yielded *Terebratulina lata* Eth. Nodular chalk, flints present, near junction with zone of *Holaster planus*. 66 NE.
136. *Terebratulina lata* Eth. on flints at 400 ft. O.D., about 250 yards west of south end of Old Castle (probable site of), Castle Hill, above east side of Falmer Bottom. About top of zone. 66 NE.
137. *Terebratulina lata* Eth. obtained at about 430 ft. O.D. from temporary trench 100 yards east of tumulus above south side of Newmarket Bottom, Falmer (by junction with Brighton County Borough Boundary). Top of zone. *Holaster planus* Mant. obtained immediately above (see No. 175). 66 NE.
138. *Terebratulina lata* Eth. obtained above 400 ft. O.D. from mole mound 50 yards north of Newmarket Plantation and same distance west of parish boundary, Falmer. 66 NE.
139. Chalk at north end of Newmarket Plantation, Falmer, about 60 yards west of parish boundary. Top beds of zone. Junction with zone of *Holaster planus* about 425 ft. O.D. 66 NE.
140. West edge of cultivated land, half-mile SW. of Newmarket Inn, St. Ann Without, at 200-foot contour. Upper part of zone, flints present. 66 NE.
141. Temporary trench just below 400 ft. O.D. on east side of valley, 140 yards west of south end of Newmarket Plantation, Falmer (south end of the 400-foot contour in valley). Flints present. About top of zone. *Terebratulina lata* Eth. obtained (see No. 180). 66 NE.
142. Small pit by track, two-thirds mile west by south of Southease Church, at 100 ft. O.D. 67 SW.

ZONE OF *HOLASTER PLANUS*

143. Chalk dug for electric pylon at about 400 ft. O.D., one-third mile SSE. of Camp on Edburton Hill, Edburton. 52 SW.
144. *Isocrinus* sp. obtained from chalk of zone just below 600 ft. O.D., 120 yards east of Camp on Edburton Hill, Edburton. 52 SW.
145. Section in bank on south side of upper track near spot 368, midway between New Barn and main road, three-quarters mile south of Saddlescombe, Newtimber. 52 SE.
146. Temporary excavation by cart track just above 300 ft. O.D., 200 yards east by south of Varncombe Barn, SW. of Varncombe Hill, Patcham. *Micraster cor-bovis* Forbes. 52 SE.

147. Temporary excavation on west side of mound above 600 ft. O.D. on North Hill at south end of Newtimber Hill, one-third mile east of Poynings Church. *Holaster planus* Mant. 52 NE.
148. Temporary excavation on Wolstonbury Hill at about 550 ft. O.D., 500 yards ENE. of Pyecombe Post Office. *Isocrinus* sp. 52 NE.
149. Bank of B.R. from main road at Clayton Hill, at east end of Wolstonbury Hill at junction with north-to-south B.R., just above 500 ft. O.D., half-mile north of Pyecombe Church. *Micraster praecursor* Rowe. 53 NW.
150. Temporary excavations showing junction of zone with zone of *Terebratulina lata*, (a) just east of B.R., quarter-mile NNE. of Pyecombe Church, (b) above B.R. 350 yards north by west of church, both excavations being on the SE. side of Wolstonbury Hill between the 400 and 500-foot contours. 53 NW.
151. Temporary excavation by hedge near 430 ft. O.D., on north side of Rag Bottom, just over half-mile east of Pyecombe Church. 53 NW.
152. Bomb-craters, (a) near 450 ft. O.D., 300 yards SSE. of Pangdean Farm, Pyecombe, (b) near 410-foot contour, 300 yards SE. of Farm. 53 SW.
153. Roadside pit in Mill Lane near drive to Clayton Windmills. *Holaster planus* Mant. Base of zone near spot-level 519 in lane. 53 NW.
154. Old chalk workings near 625 ft. O.D. by parish boundary, 200 yards SW. of Coombe Bottom Pumping Station (Burgess Hill Water Co.), Ditchling. 53 NW.
155. Junction of zone with zone of *Terebratulina lata* in centre of old chalk-pit cutting the 600- and 700-foot contours, south side of Ditchling Bostall, north of west end of Ditchling Beacon Camp. 53 NW.
156. Base of zone at 600 ft. O.D. at top of Old Limekiln pit, north of Home Brow, 400 yards east of Ditchling Beacon Camp. 53 NW.
157. Base of zone at 600 ft. O.D. in cutting, 100 yards west of Middleton Bostall, south of Westmeston Church. 53 NE.
158. Base of zone at 600 ft. O.D. in Streat Bostall, Streat. 53 NE.
159. South end of Churchyard on east side of Church of St. John under the Castle, Lewes. 54 SW.
160. Chalk section in grounds of Undercliffe House, at about 100 ft. O.D., SW. end of the Coombe, South Malling, Lewes. *Holaster planus* Mant. Typical micrasters and *Scaphites geinitzi* d'Orb. 54 SW.
161. Pit adjoining Navigation Pit, 150 yards south of Snowdrop Inn, South Street, Lewes. Section facing north entrance (portion accessible from floor of pit) yielded *Holaster planus* Mant. and typical micrasters. 54 SW.
162. Small pit near 50 ft. O.D., east of Southerham pit, 250 yards north of Southerham Farm, South Malling Without. *Micraster cor-bovis* Forbes and *Pleurotomaria* (*Leptomaria*) *perspectiva* (Mant.). 54 SW.
163. Junction of zone with zone of *Terebratulina lata* at 200 ft. O.D., quarter-mile ENE. of Southerham Farm, South Malling Without. 54 SW.
164. Edge of cultivated field against cart track near 100 ft. O.D., one-third mile NE. of Southerham Farm, South Malling Without. *Holaster placenta* Ag. obtained. A further 200 ft. to the NE. yielded *Holaster planus* Mant. and *Micraster* sp. 54 SW.
165. Junction of zone with zone of *Terebratulina lata* by parish boundary stones near 450 ft. O.D. three-quarters mile west of Glyndebourne, Glynde. 54 SE.
166. Base of zone at tumuli on Saxon Down, three-quarters mile west of Glyndebourne Farm, Glynde. *Holaster planus* Mant. 54 SE.
167. Chalk dug for posts near boundary stone and 350 ft. O.D., about 270 yards SW. of tumuli on Saxon Down, just over three-quarters mile west of Glyndebourne Farm, Glynde. *Holaster planus* Mant. 54 SE.
168. Junction of zone with zone of *Terebratulina lata* in temporary excavation just above 400 ft. O.D., 85 yards west of pond, west of Glynde Holt, Glynde. *Holaster planus* Mant., *Terebratulina lata* Eth. common on flints. 54 SE.

169. Edge of field against track on west side, at about 350 ft. O.D., one-third mile west of Caburn Bottom, WNW. of Ranscombe Camp, South Malling Without. *Holaster planus* Mant. and *Micraster cor-bovis* Forbes. 54 SE.

170. Temporary sections at south end of Mount Caburn Camp near 440 ft. O.D., 70 yards south of triangulation spot 491, Mount Caburn, Glynde. *Micraster leskei* Desm. 67 NE.

171. Bank of track at parish boundary, SE. end of Front Hill, one mile SSW. of Iford Church. *Holaster planus* Mant., *Micraster cor-bovis* Forbes. 67 NW.

172. Chalk pit above 200 ft. O.D., SE. end of Mill Hill, Rodmell, yielding *Holaster planus* Mant.; also section just below the 200-foot contour 500 yards south by east of triangulation spot 287 on Mill Hill, Rodmell. 67 SW.

173. Chalk pit above 100 ft. O.D., near barn on the NW. side of Cricketing Bottom, south of Mill Hill, Rodmell, and five-sixths mile WSW. of Southease Church. *Micraster cor-bovis* Forbes and *Holaster placenta* Ag. 67 SW.

174. Junction of zone with zone of *Terebratulina lata* at 540 ft. O.D. in bank of Juggs's Road, Kingston near Lewes, two-thirds mile west by south of Church. 66 NE.

175. Temporary trenches between 430 and 450 ft. O.D., east of tumulus above south side of Newmarket Bottom, one and a half miles SSE. of Falmer Church. *Holaster planus* Mant. and *Micraster* sp. obtained 85 yards east of tumulus. Base of zone at 430 ft. O.D. 66 NE.

176. Temporary trench at 385 ft. O.D., about 125 yards west of dew pond on Bird Brow, one and a half miles WSW. of Iford Church. *Micraster* sp. (zonal form). 66 NE.

177. By bushes at about 400 ft. O.D., SW. end of Cold Coombes, Kingston near Lewes, about 200 yards SE. of Newmarket Plantation. *Micraster* sp. and *Holaster placenta* Ag. 66 NE.

178. At 400 ft. O.D. by field boundary on west side at east end of Cold Coombes (south of pond in Coombe), Kingston near Lewes. About junction with zone of *Terebratulina lata.* 66 NE.

179. Bank of B.R. at about 430 ft. O.D., just over half-mile NE. of probable site of old Castle on Castle Hill, Kingston near Lewes. *Holaster planus* Mant. 66 NE.

180. Bomb-crater near 370 ft. O.D., a little south of SE. corner of earthwork, 100 yards west of Newmarket Plantation, Falmer. *Holaster planus* Mant. and *Terebratulina lata* Eth. Base of zone. 66 NE.

181. Evidence of zone at about 440 ft. O.D. in Newmarket Plantation, Falmer. 66 NE.

182. Railway section [3, 332, item 67] due south of Colddean, North Moulsecoomb. Since 1929 evidence for junction of this zone with zone of *Terebratulina lata* has been obtained in highest part of section above the 200 foot contour. 66 NW.

183. Railway section near 200 ft. O.D., half-mile SE. of Hollingbury Castle (Camp), south of Moulsecoomb Wild Park, Brighton. *Holaster planus* Mant. and *Isocrinus* sp. 66 NW.

184. Railway section near 200 ft. O.D., 200 yards NE. of Home Farm, Moulsecoomb, Brighton. *Holaster planus* Mant., typical micrasters and *Terebratulina lata* Eth. 66 NW.

185. *Holaster planus* Mant. obtained at 200 ft. O.D. at Hodshrove Road, above NE. end of Schools, quarter-mile east of railway, Moulsecoomb, Brighton. 66 NW.

ZONE OF *MICRASTER CORTESTUDINARIUM*

186. Chalk dug for electric pylon, east of Summersdeane Farm, two-thirds mile south of Camp on Edburton Hill, Fulking; also, electric pylon 350 yards ESE. of Paythorne Barn, three-quarters mile south of Camp on Edburton Hill. 52 SW.

187. Temporary trench 50 yards south of Dyke Park Hotel, above west end of Devil's Dyke, Poynings. *Micraster praecursor* Rowe. 52 SE.

188. Section in bank at NW. end of Dyke Station (railway now discontinued), 50 yards south of Poynings Place Farm, Poynings. Fossiliferous chalk. 52 SE.

189. West side of B.R., above 600 ft. O.D., half-mile east of Saddlescombe, 250 yards SSE. of triangulation spot on West Hill, Pyecombe. 52 SE.

190. Bank of track just above 400 ft. O.D., 100 yards south of New Barn, three-quarters mile south of Saddlescombe. Small *Echinocorys scutatus* Leske, with encrusting Polyzoa. 52 SE.

191. Bank of B.R., on west side of Varncombe Hill, near 375 ft. O.D., 200 yards NE. of Varncombe Barn, Patcham. Small *Echinocorys scutatus* Leske. 52 SE.

192. Mound above ditch near 700 ft. O.D., one-sixth mile SW. of Coombe Bottom Pumping Station (Burgess Hill Water Co.), Ditchling. 53 NW.

193. Temporary excavations near 615 ft. O.D., half-mile SE. of triangulation spot at Camp on Wolstonbury Hill, nearly half-mile NNW. of Pyecombe Church. Belt of small *Echinocorys scutatus* Leske with encrusting Polyzoa. 53 NW.

194. Temporary excavation on west side of New Barn, 350 yards north of Rag Bottom, Pyecombe; also bank of track just below spot 552, 250 yards SE. of New Barn. 53 NW.

195. Bomb-crater near 520 ft. O.D., 250 yards NNW. of pond on South Hill and quarter-mile SE. of Pangdean Farm, Pyecombe. *Micraster praecursor* Rowe. 53 SW.

196. Small pit at 400 ft. O.D., 50 yards NE. of barn with B.M. 365.45, Lower Standean, Ditchling. 53 SW.

197. Section in top of Middleton Bostall near 670 ft. O.D., half-mile south of Westmeston Church. 53 NE.

198. Bank on west side by spot 665 at top of Streat Bostall, one and a half miles south of Streat Church. Small *Echinocorys scutatus* Leske. Micrasters in chalk just below, in Bostall. Basement beds of zone. 53 NE.

199. Section at 560 ft. O.D. above west side of B.R., with small *Echinocorys scutatus* Leske at 570 ft. O.D., 250 yards SE. of Blackcap, and half-mile WSW. of Courthouse Farm, St. John Without. 53 NE.

200. Chalk dug for electric pylon at 400 ft. O.D., 100 yards south of Coombe Plantation, nearly two-thirds mile west by south of Offham Church. 54 SW.

201. South bank of Kingsley Road, Lewes, at 100 ft. O.D., 50 yards north of west end of King Henry's Road, half-mile WNW. of Church of St. John under the Castle, Lewes. Small *Echinocorys scutatus* Leske. 54 SW.

202. Base of zone at 100 ft. O.D. at top end of Chapel Hill, 200 yards ESE. of Church of St. Thomas à Beckett, Cliffe, Lewes. 54 SW.

203. Temporary section below 50 ft. O.D., cut for building new County Council offices in Southover Road, between Watergate Lane and St. Andrew's Lane, Lewes. *Micraster praecursor* Rowe. 54 SW.

204. About 100 yards of edge of field on south side of Juggs's Road at 200 ft. O.D. and above, half-mile east of Ashcombe Hollow and two-thirds mile WSW. of Waterworks (Lewes Corporation), Kingston near Lewes. Bottom of 54 SW.

205. Temporary excavation near base of zone, above 400 ft. O.D., at about 100 yards south of dew pond, west of Glynde Holt, half-mile west of 'The Lacys', Glynde (evidence supported by other excavations near spot). Small *Echinocorys scutatus* Leske. 54 SE.

206. Temporary excavation by tumulus with triangulation spot 489, about 170 yards SSE. of last-mentiond evidence, nearly two-thirds mile WNW. of Glynde Church. 54 SE.

207. Small *Echinocorys scutatus* Leske obtained from temporary excavation above east side of Caburn Bottom near 275 ft. O.D., 250 yards SE. of Rifle Butts Targets, and about one mile WNW. of Glynde Church. 54 SE.

208. Bomb-crater near 300 ft. O.D. above east side of Caburn Bottom, 300 yards NNW. of Mount Caburn Camp, Glynde. *Pavolunulites subquadrata* Brydone. High in zone. 54 SE.

209. Two temporary excavations above 400 ft. O.D. at Ranscombe Camp above west side of Caburn Bottom, one-third mile WNW. of Mount Caburn Camp, (1) excavation one-third mile south of Rifle Butts targets yielded small specimen of *Echinocorys scutatus* Leske and *Holaster placenta* Ag., (2) excavation 50 yards to the NW. of (1) yielded *Micraster praecursor* Rowe. Low in zone. 54 SE.

210. Chalk dug at west end of ditch on north side of Mount Caburn Camp. *Micraster praecursor* Rowe. 67 NE.

211. Temporary excavation above 600 ft. O.D., 300 yards west of 'stones' near Long Barrow on Six-inch Sheet, quarter-mile west of Firle Beacon; also excavations above 600 ft. O.D., 25 yards west and NW. of two tumuli, half-mile west of Firle Beacon, West Firle. Top east end of 67 SE.

212. Small section just above 500 ft. O.D. on Swanborough Hill, two-thirds mile WSW. of Swanborough Farm, west of Iford Church. *Micraster praecursor* Rowe. 67 NW.

213. *Micraster cortestudinarium* Goldf. at 330 ft. O.D., *Echinocorys scutatus* Leske (small) at 350 ft. O.D., in north bank of cart track to Whiteway Bottom, one mile SSW. of Iford Church. (Evidence in Iford Parish, by parish boundary.) Basement beds of zone. Top of 67 SW.

214. Bomb-crater above 600 ft. O.D., about 100 yards south of Juggs's Road. and half-mile north of Old Castle (probable site of), on Castle Hill, Kingston near Lewes. High in zone. 66 NE.

215. Just above 600 ft. O.D., south of spot-level 586 by Juggs's Road, 200 yards SW. of ponds by tumulus, five-sixths mile WSW. of Manor House, Kingston near Lewes. *Reticrisina obliqua* d'Orb. 66 NE.

216. Bomb-crater near 560 ft. O.D., one-sixth mile east of Newmarket Farm at south end of Newmarket Hill, Kingston near Lewes. *Pavolunulites subquadrata* and other Polyzoa. About junction with *Micraster coranguinum* zone. 66 NE.

217. Temporary trench at 475 ft. O.D., centre of brow 500 yards NW. of dew pond on Bird Brow and five-sixths mile SW. of Church, Kingston near Lewes. *Micraster praecursor* Rowe. 66 NE.

218. Temporary trench at about 450 ft. O.D., on north side of dew pond on Bird Brow, north end of Balsdean Bottom, and one and a half miles WSW. of Iford Church. *Reticrisina obliqua* d'Orb. 66 NE.

219. Temporary trench at about 425 ft. O.D., on east side of Castle Hill, 350 yards NE. of Old Castle (supposed site of), above west side of north end of Balsdean Bottom, Iford. *Micraster cortestudinarium* Goldf. Near base of zone. 66 NE.

220. About 460 ft. O.D. on south side of Spur, quarter-mile NW. of Bird Brow, Kingston near Lewes. *Cretirhynchia subplicata* (Mantell) and *Reticrisina obliqua* d'Orb. 66 NE.

221. Temporary trench by fencing, centre of Spur above 500 ft. O.D., quarter-mile east of Castle Hill, Kingston near Lewes. 66 NE.

222. Small *Echinocorys scutatus* Leske and *Reticrisina obliqua* d'Orb. from temporary trench near 470 ft. O.D., above north side of Falmer Bottom and quarter-mile west of centre of Castle Hill, Kingston near Lewes. 66 NE.

223. Intrenchment, quarter-mile SSW. of Broadpit Pond, Iford, above east side of Balsdean Bottom, (a) at about 540 ft. O.D. *Reticrisina obliqua* d'Orb., (b) at about 560 ft. O.D. *Multelea* sp. and *Pharetrospongia strahani* Sollas, (c) basement beds of zone of *Micraster coranguinum* at about 600 ft. O.D. *Serpula ilium* Sow. and *Pavolunulites subquadrata* Brydone. 66 NE.

224. Spur at about 375 ft. O.D., 400 yards west of Newmarket Plantation, south of Loose Bottom, Falmer. *Pharetrospongia strahani* Sollas. 66 NE.

225. Near 300 ft. O.D., 200 yards east of pond in Loose Bottom, Falmer. At 200 ft. south of pond, chalk yielded *Reticrisina obliqua* d'Orb. 66 NE.

226. About 325 ft. O.D., 150 yards west of earthwork, above south side of Loose Bottom, Falmer. 66 NE.
227. In Newmarket Plantation on east side, near 470 ft. O.D. (15 feet below top of Plantation). Low in zone. 66 NE.
228. Edge of cultivated land by track 100 yards SW. of Newmarket Plantation, Falmer. Small *Echinocorys scutatus* Leske, *Reticrisina obliqua* d'Orb. and *Cistella* (*Argiope*) *bronni* von Hag. Low in zone. 66 NE.
229. Seam of larger *Echinocorys scutatus* Leske at NE. corner of cultivated land at parish boundary, about 500 ft. O.D., 60 yards south of Newmarket Plantation, one mile SE. of Falmer Church. High in zone. 66 NE.
230. North end of intrenchment in Loose Bottom at 300 ft. O.D., quarter-mile west of earthwork and west of Newmarket Plantation, Falmer. 66 NE.
231. Temporary trenches (three together) at about 560 ft. O.D. on east side of Bullock Hill, north of footpath, 550 yards east of triangulation spot, Woodingdean. Near top of zone. 66 NE.
232. South edge of cultivated land near 380 ft. O.D., quarter-mile south of south portion of Westlain Plantation, three-quarters mile SSW. of Falmer Church. *Reticrisina obliqua* d'Orb. 66 NE.
233. Hard belt of chalk at 225 ft. O.D. (base of zone) near SW. end of Westlain Belt, one-third mile SSW. of Falmer Pumping Station (Waterworks). At about 240–50 ft. O.D. Chalk yielded small *Echinocorys scutatus* Leske and *Cretirhynchia subplicata* (Mantell). 66 NE.
234. Temporary excavations near 270 ft. O.D., on spur quarter-mile NE. of Lower Bevendean Farm, Brighton. New housing estate. 66 NE.
235. Cultivated land on south side of road to Lower Bevendean in area, one-sixth mile east of north end of Brighton Borough Sanatorium grounds, at about 300 ft. O.D. *Micraster praecursor* Rowe and small *Echinocorys scutatus* Leske (common). Basement beds of zone. 66 NW.
236. Bank near top of track adjoining Colddean Nursery at NE. end of Moulsecoomb Wild Park, Brighton. *Micraster praecursor* Rowe and *Echinocorys scutatus* Leske. Base of zone near 225 ft. O.D. 66 NW.
237. Temporary trench on west side at north end of Westfield Crescent by junction with Wilmington Way, just over half-mile WNW. of Hollingbury Castle (Camp), Brighton, above the 300 foot contour. Hard band of yellow stained chalk yielding *Micraster*. Top beds of zone. This band is probably identical with the one at the pit by Golf Links and Eastdean Road, Eastbourne [**5**, 520]. 66 NW.
238. Chalk at about 410–15 ft. O.D., new road work on housing estate, quarter-mile NW. of Hollingbury Castle (Camp), Brighton. 66 NW.
239. Rough, lumpy chalk, consisting of yellowish lumps in a soft matrix, one and a quarter feet in thickness, with a bed of nodular flints above, exposed temporarily for a few feet at about 360 ft. O.D., half-mile NW. of south end of Hollingbury Castle (Camp), Brighton. New housing estate. *Micraster praecursor* Rowe. 66 NW.
240. Temporary exposure at about 330 ft. O.D., half-mile NNW. of centre of Hollingbury Castle (Camp), Brighton. New housing estate. Near top of zone. 66 NW.
241. Pumping Station (Brighton Corporation Waterworks) near 200 ft. O.D., nearly quarter-mile NE. of triangulation spot on High Hill, Rottingdean. At depth of 215–18 ft. below surface, chalk yielded *Micraster* and other fossils of zone. The chalk at the surface is in the zone of *Micraster coranguinum*. 66 SE.

ZONE OF *MICRASTER CORANGUINUM*

(a) Basement Beds of Zone—*i.e.* to Top of Trochiliopora Bed

242. Chalk yielding *Trochiliopora gasteri* Thomas, from temporary excavations, (a) by triangulation spot 708 on Truleigh Hill, (b) 80 yards east of Truleigh Hill Barn with B.M. 667.5 and (c) at about 525 ft. O.D., one-third mile SSE. of Truleigh Hill Barn, Edburton. 52 SW.

243. Chalk dug for electric pylon near spot 254 in Summers Deane, 300 yards south of pond and half-mile south of Paythorne Barn, Fulking. *Trochiliopora.* 52 SW.
244. Two small overgrown pits above 400 ft. O.D., 500 yards north of Reservoir on Sweet Hill, east of Varncombe Hill, Patcham. *Trochiliopora.* 52 SE.
245. Temporary excavation at, or just above, 200 ft. O.D., south of track with the word 'stone' at intervals shown on Six-inch Sheet, east side of Carden Avenue, Patcham. Near junction with zone of *Micraster cortestudinarium.* 66 NW.
246. Temporary exposure on south side of Carden Avenue, Patcham, between Warmdene Road and the Wilmington Hotel. Yellow stained Chalk. Chalk exposed in Carden Avenue during temporary excavations for new housing purposes between Warmdene Road and Sunnydale Avenue wholly in zone. 66 NW.
247. Temporary excavation near 240 ft. O.D., by old footpath (north side) with word 'stone' at intervals on Six-inch Sheet, 80 yards north of Wilmington Way and half-mile east of Ashburnham House, Patcham. Trochiliopora Bed. 66 NW.
248. Centre of spur just above 350 ft. O.D., excavation for new road (Crabtree Avenue) continuing northward from Westfield Crescent (north of footpath with word 'stone' at intervals on Six-inch Sheet), Patcham. 66 NW.
249. Temporary excavations for new road at 440 ft. O.D., on housing estate one-third mile WNW. of Hollingbury Castle (Camp), Brighton. 66 NW.
250. Garden of new house at NW. corner of Braybon Avenue, below the 200 foot contour, 50 yards NW. of Church, Patcham. 66 NW.
251. Garden of 23 Braybon Avenue, at top north corner of Old Farm Road (above 200 ft. O.D.), Patcham. Trochiliopora bed. 66 NW.
252. Chalk near 270 ft. O.D., SW. end of Plantation on north side of Peacock Lane, Withdean, Brighton. 66 NW.
253. East bank of new road (Lyminster Avenue), 60 yards east of north end of Westfield Crescent, half-mile WNW. of Hollingbury Castle (Camp), Brighton. *Trochiliopora.* 66 NW.
254. Bank on south side of Highfield Crescent, above 300 ft. O.D., about 120 yards east of west end of Crescent, two-thirds mile west by north of centre of Hollingbury Castle (Camp), Brighton. 66 NW.
255. Temporary trench at about 450 ft. O.D., 200 yards NE. of north end of Hollingbury Castle (Camp), Brighton. *Trochiliopora.* 66 NW.
256. Chalk at about 435 ft. O.D., 50 yards east of small earthwork, quarter-mile east of south end of Hollingbury Castle (Camp), Brighton. *Trochiliopora.* 66 NW.
257. Railway section on north-west side, NW. of south end of Preston Barracks, Lewes Road, Brighton. *Trochiliopora.* 66 NW.
258. Basement beds of zone near triangulation spot 813 on Ditchling Beacon. 53 NW.
259. Chalk from rabbit burrows just north of dew pond on Plumpton Plain, 70 yards south of 700-foot contour, two-thirds mile SSE. of Plumpton Church, also similar evidence, quarter-mile SW. of target for Rifle Range, 200 yards SE. of tumuli on Plumpton Plain, half-mile SSW. of Half Moon Inn, Plumpton. Trochiliopora Bed. 53 NE.
260. Trochiliopora Bed, area of tumuli on Mount Harry, Hamsey. 53 NE
261. Electric pylon near 400 ft. O.D., Broad Shackles, one-third mile SE. of Four Lords' Burgh and east of Buckland Bank, Falmer. Chalk dug for pylon in Trochiliopora Bed. 53 SE.
262. Chalk in area of tumulus and triangulation spot on Swanborough Hill, one mile WSW. of Iford Vicarage. 67 NW.
263. Chalk above 300 ft. O.D., 80 yards NW. of tumuli on Heathy Brow, above south side of Whiteway Bottom, Iford. Trochiliopora bed. 67 SW.

264. Chalk dug for fencing 35 ft. below top of Castle Hill spur on east side, at about 550 ft. O.D., one-third mile south of Juggs's Road, Kingston near Lewes. *Trochiliopora.* 66 NE.
265. Chalk yielding *Trochiliopora* at about 450 ft. O.D., at south end of NNE. valley entrenchment above south side of SW. end of Loose Bottom, Falmer. 66 NE.
266. Road bank at parish boundary, just below 500 ft. O.D., SW. end of Newmarket Hill, Falmer. 66 NE.
267. Temporary trenches about 570 ft. O.D., 200 yards west of triangulation spot on Newmarket Hill (west of parish boundary), Falmer. 66 NE.
268. Temporary trenches in area from north end of Old Castle (supposed site of), to about 100 yards north, at 540–550 ft. O.D., Castle Hill, Kingston near Lewes. 66 NE.
269. Small chalk pit immediately above 300 ft. O.D., quarter-mile north of Newmarket Plantation and one mile ESE. of Falmer Church; also at 310 ft. O.D., 50 yards west of pit, and at 325 ft. O.D., 100 yards SW. of pit. 66 NE.
270. Evidence of Trochiliopora Bed in area of triangulation spot on Newmarket Hill, Kingston near Lewes, west side of B.R., west of pond. *Trochiliopora* obtained at 615 ft. O.D., 150 yards west of pond. Yellow stained nodular chalk present. 66 NE.
271. Temporary evidence near 550 ft. O.D., above SW. corner of Cold Coombes, 80 yards north of Juggs's Road, Kingston near Lewes. 66 NE.
272. Temporary excavation at 500 ft. O.D., by fencing above west side of Cold Coombes, Kingston near Lewes, one-eighth mile SE. of Newmarket Plantation. 66 NE.
273. Edge of cultivated land by parish boundary near 560 ft. O.D., about 340 yards SSE. of Newmarket Plantation, Falmer. 66 NE.
274. Trochiliopora Bed on cultivated land by track on north side of Newmarket Hill (between track and 500 foot contour), one-third to one-quarter mile SW. of Newmarket Plantation, Falmer. 66 NE.
275. Temporary excavations for new housing estate near 325 ft. O.D., on spur, quarter-mile NE. of Lower Bevendean Farm, Brighton. Hard yellow stained fossiliferous chalk. Trochiliopora Bed. 66 NE.
276. Chalk at SW. edge of cultivated land near 350 ft. O.D., quarter-mile NE. of Upper Bevendean Farm, and quarter-mile south of Cambridgeshire Farm, south of Falmer Hill, Falmer. Band of hard yellow stained chalk. 66 NE.
277. Temporary trench about 150 yards NNE. of pond in Loose Bottom, quarter-mile NW. of Newmarket Plantation, Falmer. 66 NE.
278. Temporary trench at 400 ft. O.D., 100 yards south of tumuli on Offham Hill, 250 yards west of Chalk Pit Inn, Offham. Trochiliopora Bed. Also temporary trench by tumuli on Offham Hill above 400 ft. O.D. 54 SW.
279. Edge of field on east side of footpath at about 200 ft. O.D., south of Hill Road and 300 yards WNW. of King Henry's Road, Lewes. 54 SW.
280. Temporary section at 100 ft. O.D., on east side of north end of Westgate Street, Lewes, 50 yards west of Lewes Castle (remains of). Trochiliopora Bed. 54 SW.
281. Temporary excavation at south end of Keere Street, Lewes. 54 SW.
282. Temporary excavations (air raid shelters) on vacant plot of ground on north side of Priory Street at west corner of Garden Street, Southover, Lewes. 54 SW.
283. Temporary excavation in Southover High Street, Lewes, below NW. corner of churchyard, 40 yards west of church, yielding *Trochiliopora.* Other evidence in NW. corner of churchyard; also in portion of churchyard immediately south of west end of Priory Crescent, Lewes. 54 SW.
284. Bank on south side of Bell Lane at about 50 ft. O.D., immediately south of west end of brewery, quarter-mile west of Southover Church, Lewes. Trochiliopora Bed. 54 SW.
285. Temporary trench at top of field by R. D. By., 50 yards north of Juggs's Road, half-mile SSE. of Houndean Barn, three-quarters mile SE. of Ashcombe House, St. Ann Without, Lewes. Trochiliopora Bed. 54 SW.

286. Temporary excavations on Cliffe Hill, east of the Coombe, South Malling Without, Lewes, (a) about 490 ft. O.D., 60 yards east of B.M., 466–46, (b) area of triangulation spot. Trochiliopora Bed. 54 SW.

287. Basement beds of zone at 400 ft. O.D., 200 yards WSW. of north tumulus, 470 yards west of Speaker's Holt, east of Caburn Bottom, Glynde. 54 SE.

288. Temporary excavation near 440 ft. O.D., just west of spot 455, 40 yards north of Mount Caburn Camp, Glynde. Trochiliopora Bed. Downthrow side of Caburn fault. 67 NE.

289. Temporary excavation at about 530 ft. O.D., 200 yards SE. of White Lion Pond, Beddingham. 67 SE.

290. Temporary excavation, 320 yards ENE. of Males Burgh (tumulus), WNW. of Overhill Lodge, West Firle. Starfish bed. 67 SE.

291. Temporary excavation on east side of B.R., 200 yards east of north tumulus of Lord's Burghs (tumuli), just over quarter-mile SSE. of Overhill Lodge, West Firle. Trochiliopora Bed. 67 SE.

292. Temporary excavation at 400 ft. O.D., one-third mile ESE. of south tumulus of Lord's Burghs (tumuli), half-mile SE. of Overhill Lodge, West Firle. Trochiliopora Bed. 67 SE.

293. Evidence at Long Barrow near spot 687 west of Firle Beacon, north of Beacon Bottom, West Firle. *Pavolunulites subquadrata* Brydone. 67 SE.

(b) ALL CHALK BETWEEN TROCHILIOPORA BED AND UPPER LIMIT OF ZONE.

294. Chalk dug for electric pylon one-third mile south of pond in Summers Deane, near B.M. 233.5, half-mile NE. of Camp on Thundersbarrow Hill, also pylon in Hazelholt Bottom, half-mile ENE. of Thundersbarrow Hill Camp. 52 SW.

295. Chalk dug for electric pylon just above 200 ft. O.D., 500 yards NNW. of Mile Oak Barn, a little over half-mile east of Thundersbarrow Hill Camp. *Micraster coranguinum* Leske. 65 NW.

296. Small pit, 50 yards south of Atlingworth Barn, Mount Zion, Portslade. 52 SE.

297. Pit at 500 ft. O.D., on east side of Varncombe Hill, NW. of Sweet Hill, Patcham. Strong tabular flint seam in pit. 52 SE.

298. Section near top of zone at about 250 ft. O.D., on north side of Ladies Mile, Patcham, 200 yards east of Methodist Church. *Micraster coranguinum* Leske. Belt with *Conulus* in section. 53 SW.

299. Section in north bank of road about 75 yards WSW. of Stanmer Church, east of old chalk pit. 53 SW.

300. Chalk pit in Limekiln Wood, one-third mile north of Stanmer Church. *Micraster coranguinum* Leske. 53 SW.

301. Road widening SE. bank of Mill Road, Patcham, between entrance to Windmill and south of Patcham Pumping Station (Waterworks), near top of zone by entrance to Windmill. 53 SW., 66 NW.

302. Temporary trench dug for drainage in Surrenden Close on north side of Surrenden Road, Withdean, Brighton. 66 NW.

303. Section in bank near 200 ft. O.D., about 70 yards north of Newman's Barn, west of railway, Withdean, Brighton. 66 NW.

304. Two allotments on east side of London Road, 100 yards east of Withdean Farm (between Carden Avenue and Peacock Lane), Withdean, Brighton. *Pelmatopora crepidaria* Lang [B.M. (N.H.) Reg. No. D 37434], kindly identified by Dr. H. Dighton Thomas. 66 NW.

305. In copse of Withdean Park (west end) 250 yards east of Withdean Farm, on south side of Carden Avenue, Brighton. 66 NW.

306. Spur near 330 ft. O.D., half-mile NE. of Hollingbury Castle (Camp), Brighton, on edge of cultivated land. 66 NW.

307. Chalk pit at 300 ft. O.D., 100 yards south of Mary Farm, Falmer. 53 SE.

308. Strong coranguinum tabular flint seam of Rowe, exposed in bank of road to Lower Roedale at about 300 ft. O.D., 100 yards east of Ditchling Road at junction with Balfour Road, Brighton. 66 NW.

309. Chalk dug for three electric pylons, (a) two-thirds mile ENE. of Mary Farm, (b) nearly half-mile NE. of Mary Farm, (c) one-third mile NNE. of Mary Farm, east of Stanmer Down, Falmer. 53 SE.
310. Cutting in bank of track on north side of main road, 400 yards ENE. of Newmarket Inn, St. Ann Without, Lewes. High in zone. 53 SE.
311. Temporary 200 ft. E. W. trench, above 400 ft. O.D., on west side of Lewes Race Course, half-mile north of Ashcombe Plantation, St. Ann Without, Lewes. Near top of zone. Within 300 yards north of this trench four other trenches were dug, all in the zone. 53 SE.
312. Temporary trenches on Falmer Hill above 500 ft. O.D., west of the Drove Road, three-quarters mile south of Falmer Church to south of east end of Westlain Plantation. 66 NE.
313. Temporary trenches in Juggs's Road area, around the 600-foot contour, above south end of Cold Coombes, Kingston near Lewes. 66 NE.
314. By north side of Westlain Belt, west side of track, 300 yards SSE. of Falmer Pumping Station (Brighton Corporation Waterworks). 66 NE.
315. Temporary trenches in area of tumuli at 500 ft. O.D., The Bostle, Rottingdean. 66 SE.
316. Temporary trench at 400 ft. O.D., by wall on south side of Warren Farm Schools, Woodingdean, NNW. of Ovingdean Church. *Micraster coranguinum* Leske. 66 SE.
317. Small pit by track on east side of Houndean Bottom above 100 ft. O.D., two-thirds mile ENE. of Ashcombe Farm, St. Ann Without, Lewes. *Micraster coranguinum* Leske. Near top of zone. 54 SW.
318. Temporary excavation by track on Downs, above 200 ft. O.D., half-mile west of St. Anne's Church, Lewes. High in zone. 54 SW.
319. Railway section at west end of tunnel on south side of Love Lane, half-mile WSW. of Southover Church, Lewes. 54 SW.
320. Plot of ground at 200 ft. O.D., on south side of Juggs's Road, two-thirds mile WSW. of Southover Church, Lewes. Strong tabular flint seam near surface. 54 SW.
321. Three old chalk pits above east side of Blackstone Bottom, Alfriston, (a) quarter-mile east of Five Lords' Burgh, (b) one-third mile ENE. of triangulation spot on Norton Top, and (c) one-third mile ESE. of the triangulation spot just mentioned. 68 SW.
322. Old chalk pit, 200 yards west of B.M. 495.9, near tumuli, five-sixths mile SW. of Bopeep Chalk Pit, Alciston. 68 SW.
323. Old chalk pit near B.M. 455.3, quarter-mile north of Five Lords' Burgh, five-sixths mile SW. of Bostal Hill, Alciston. 68 SW.
324. Temporary excavation just below 400 ft. O.D., 70 yards west of parish boundary, one mile NE. of Tarring Neville Church. 67 SE.
325. Small pit, above 400 ft. O.D., on east side of B.R. on Blackcap Hill, one-third mile south of Blackcap Farm, Beddingham. Top beds of zone. Junction with Uintacrinus Subzone on south side of pit. 67 SE.
326. Temporary excavation at 350 ft. O.D., 125 yards north of pond on Denton Hill, Denton. 67 SE.
327. Old chalk pit, 250 yards SW. of Hill Buildings, five-sixths mile SSW. of Southease Church. 67 SW.

ZONE OF *MARSUPITES TESTUDINARIUS*

SUBZONE OF *UINTACRINUS*

328. Temporary excavation just north of 500 yards range at Rifle Range, quarter-mile NW. of Mileoak Barn, east of Camp on Thundersbarrow Hill. 65 NW.
329. Cutting in west bank of track near 350 ft. O.D., 80 yards SW. of Atlingworth Barn, on east side of Mount Zion, Portslade. 52 SE.
330. Two temporary trenches on east side of Dyke Road, east of Skeleton Hovel, one and one-third mile north of West Blatchington Church, (1) just below 500 ft. O.D., yielding medium ossicles, (2) just above 500 ft. O.D., yielding large ossicles. Obtained smooth plates of *Marsupites* at 520 ft. O.D. 52 SE.

331. Small section at 350 ft. O.D., 200 yards ENE. of tumulus with triangulation spot on Round Hill, five-sixths mile NNE. of Hangleton Church. 65 NE.
332. Chalk dug for electric pylon above 400 ft. O.D., 100 ft. east of Saddlescombe Road, about 80 yards north of junction with Dyke Road, three-quarters mile NW. of Redhill Cottages, Brighton. Top of 65 NE.
333. Chalk from uprooted tree on Coney Hill, Patcham, above 300 ft. O.D., 70 yards NNW. of air-shaft to railway tunnel. 53 SW.
334. Section in hedge of field near 250 ft. O.D., 150 yards NNE. of Newman's Barn, west of railway and nearly half-mile SE. of Patcham Windmill, Brighton. 66 NW.
335. Chalk dug for air-raid shelters above the 200-foot contour, 150 yards NE. of Ashburnham House (between High View and Overhill Way), one-third mile SSE. of All Saints' Church, Patcham. (Small outlier.) 66 NW.
336. Edge of field at north end at about 330 ft. O.D., 325 yards east of Ditchling Road and 120 yards north of Brighton County Borough boundary, half-mile NNE. of Hollingbury Castle (Camp). 66 NW.
337. Top of field at SW. end above 400 ft. O.D., on east side of Ditchling Road, within 50 yards north of Brighton County Borough boundary and north of Hollingbury Castle (Camp). 66 NW.
337a. Railway allotments on east side of Ditchling Road near 200 ft. O.D., above tunnel east of London Road Station, Brighton; also, bank at east end of north platform at Station. 66 NW.
338. Temporary excavations in area above 600 ft. O.D., between 25 yards and 250 yards north of pond on west side of Ditchling Road and west of Piddingworth Plantation, Ditchling. Smooth plates of *Marsupites* obtained 25 yards north of pond indicating junction of subzones of *Marsupites* and *Uintacrinus* at that spot. 53 SW.
339. Temporary trenches in area of Ladies Mile, Patcham, (a) 40–50 yards long on south side of Ladies Mile, south of Eastwick Barn near 350 ft. O.D., (b) above 400 ft. O.D. near junction of track from Eastwick Barn to Ladies Mile on north side, (c) between spot 374 and the 400-foot contour on north side of Ladies Mile. 53 SW
340. Temporary excavation in Stanmer Park on west side of road to mansion, west of Wilkin's Folly, quarter-mile SE. of the mansion, Stanmer. *Bourgueticrinus* (form with tubercles). 53 SE.
341. Temporary excavations at about 200 ft. O.D. (south of cultivated land) in Colddean Belt, Stanmer Park, 250 yards WSW. of Falmer Pumping Station (Brighton Corporation Waterworks). 66 NE.
342. Chalk dug for posts at south end of 500-foot contour, Buckland Bank, one mile ENE. of Mary Farm, Falmer. 53 SE.
343. Chalk dug for posts at 480 ft. O.D., on west side of B.R., 100 yards south of last item. 53 SE.
344. Chalk from rabbit burrows above 400 ft. O.D., at top NE. end of Moon's Plantation, 300 yards SSE. of Mary Farm, Falmer. (a) Ossicles and plates of *Uintacrinus*, (b) 50 yards to the south of (a), smooth plates of *Marsupites*, (c) 70 yards to the south of (b), ornate plates of *Marsupites*. 53 SE.
345. Temporary evidence about 70 yards east of pond on Balmer Down, Falmer. 53 SE.
346. Section in bank just above the 200-foot contour on north side of Long Hill, 250 yards west of Ashcombe Plantation and one-third mile north of Newmarket Inn, St. Ann Without, Lewes. Junction with *Marsupites* subzone in section. Smooth plates of *Marsupites* obtained since Survey's publication [13, 53]. 53 SE.
347. Railway bank on south side, south of Lower Housedean Cottages, Falmer. 53 SE,
348. Temporary excavation at 440 ft. O.D., 150 yards east of the Drove Road, half-mile south of Falmer Church. 66 NE.

349. 240 ft. E.–W. temporary trench, west of Lewes Race Course, reaching 400-foot contour at east end, 300 yards north of tumulus with triangulation spot and about 750 yards north of Ashcombe Plantation, St. Ann Without, Lewes. 53 SE.

350. 280 ft. E.–W. temporary trench, west of Lewes Race Course, just above the 400-foot contour, at east end, 150 yards north of tumulus with triangulation spot and just over one-third mile north of Ashcombe Plantation, St. Ann Without, Lewes. Lower third of trench yielding *Uintacrinus*; upper two-thirds yielding smooth plates of *Marsupites*. 53 SE.

351. Top of field between 200 and 215 ft. O.D., quarter-mile west of Houndean Barn, one-third mile ENE. of Ashcombe Farm, St. Ann Without, Lewes. 54 SW.

352. Rabbit burrows on east side of Lewes Race Course, midway between Race Course and the 300-foot contour, 350 yards NNW. of the two miles starting-post, west of Houndean Bottom, St. Ann Without, Lewes. 54 SW.

353. By north stone shown on Six-inch Sheet above 200 ft. O.D., 200 yards NE. of Ashcombe House, St. Ann Without, Lewes. 54 SW.

354. Three temporary trenches on east side of road over Downs to Lewes Race Course, above 300 ft. O.D., 160 yards west to 200 yards WNW. of Reservoir (Lewes Corporation Waterworks) and quarter-mile NE. of Houndean Barn, St. Ann Without, Lewes. 54 SW.

355. Houndean Housing Estate, Lewes, west of H.M. Prison. Temporary excavation, 250 yards east by south of Houndean Barn, St. Ann Without, Lewes. 54 SW.

356. Chalk pit on east side of Sheepcote Valley, Ovingdean, above 300 ft. O.D., one-third mile SSE. of Racehill Farm, Brighton. 66 SE.

357. Temporary excavation at 400 ft. O.D., 500 yards SE. of Warren Farm Schools, Woodingdean. 66 SE.

358. Two temporary E.–W. trenches about 90 and 240 yards south of the 400-foot contour, on west side of B.R., north by west of tumulus on Mount Pleasant and SSE. of Warren Farm Schools, Woodingdean. 66 SE.

359. Near triangulation spot, and about 400 ft. O.D., on Highdole Hill, five-sixths mile NNW. of Telscombe Village. 67 SW.

360. Temporary excavation just above 300 ft. O.D., 500 yards SW. of triangulation spot on Highdole Hill, five-sixths mile NW. of Telscombe Church. 67 SW.

361. Temporary trench on north slope of valley on west side of parish boundary about 650 yards east by north of Telscombe Church. 67 SW.

362. North end of cultivated field on south side of parish boundary 300 yards north of Page's New Barn, South Heighton. 67 SE.

363. Small overgrown pit at 400 ft. O.D., on east side of parish boundary, half-mile west of Blackcap Hill, Beddingham. 67 SE.

364. Pit on Blackcap Hill above 400 ft. O.D., 350 yards west of Toy Farm, Beddingham. Junction with zone of *Micraster coranguinum* in pit. 67 SE.

365. Overgrown pit below 400 ft. O.D., in boundary copse, 300 yards SW. of Toy Farm, Beddingham. 67 SE.

366. Road bank on north side near 200 ft. O.D., 25 yards west of boundary stone, Cantercrow Hill, Denton Road, Denton. 67 SE.

367. Bank of track at about 300 ft. O.D., on north side of parish boundary at Gardener's Hill, ENE. of South Heighton Church. 67 SE.

368. Temporary excavation just above overgrown pit at 400 ft. O.D., one-sixth mile SE. of pond on Denton Hill, Denton. 67 SE.

369. Overgrown pit at about 450 ft. O.D., 120 yards WSW. of triangulation spot on Norton Top, Denton. 68 SW.

370. Overgrown pit 200 yards SSW. of triangulation spot on Norton Top, Denton. 68 SW.

371. By parish boundary and tumulus 50 yards south of spot 381, half-mile NNE. of Blackstone Barn, Bishopstone. 79 NW.

SUBZONE OF *MARSUPITES*

372. Rabbit burrows at 300 ft. O.D., 100 yards NE. of targets at Rifle Butts, quarter-mile ESE. of Camp on Thundersbarrow Hill. 65 NW.
373. Bank of track to Southwick Hill at 200 ft. O.D., 150 yards south of Mile Oak Barn, Southwick. 65 NW.
374. In bank by track above 350 ft. O.D., on north-west side of Cockroost Hill, a little over half-mile WSW. of Atlingworth Barn, Portslade. 52 SE.
375. Cutting in west bank of track near 350 ft. O.D., one-sixth mile south of Atlingworth Barn on east side of Mount Zion, Portslade. 52 SE.
376. Temporary trench just below 400 ft. O.D., below north side of Mill Road, Patcham, quarter-mile north of Red Hill Reservoir, Brighton. 65 NE.
377. Top west side of field at north end of spur at 300 ft. O.D., about 450 yards SW. of south end of railway tunnel, Patcham, *Terebratulina rowei* Kitch., obtained at NW. corner of field, 100 yards west of tunnel. 66 NW.
378. Overgrown pit in field above 300 ft. O.D., 300 yards SE. of Patcham Windmill, one-third mile west of railway. 66 NW.
379. Temporary section in Hillside Way on north side of Tongdean Lane, near 270 ft. O.D., one-third mile west of railway, Withdean, Brighton. 66 NW.
380. Temporary excavation at north end of Preston Park Avenue, Brighton, about 50 yards south of B.M. 161.53, quarter-mile ESE. of St. John's Church, Preston. 66 NW.
381. Cultivated field above 500 ft. O.D., between Upper Lodge Wood and Rocky Clump, two-thirds mile NW. of Stanmer Church. 53 SW.
382. At 460 ft. O.D., in field on west side of Ditchling Road, about 320 yards SW. of Upper Lodges, Stanmer Park, and five-sixths mile west of Stanmer Church. 53 SW.
383. Edge of cultivated land on west side of Ditchling Road between B.M. 544.59 and R.D. By., just under one mile NW. of Stanmer Church. *Terebratulina rowei* Kitch. 53 SW.
384. Small pit in field, 500 yards west of the Menagerie, west of Great Wood in Stanmer Park. 66 NW.
385. Edge of north end of field at about 380 ft. O.D., 200 yards east of Ditchling Road, 150 yards north of Brighton County Borough boundary, half-mile north by east of Hollingbury Castle (Camp). *Terebratulina rowei* Kitch. 66 NW.
386. Temporary excavations at Marquee Brow just south of old pit at 200 ft. O.D., Stanmer Park, one-sixth mile NW. of Falmer Pumping Station (Brighton Corporation Waterworks). *Terebratulina rowei* Kitch. 66 NE.
387. Old pit at 200 ft. O.D., at north-east end of Marquee Brow, Stanmer Park. 66 NE.
388. Temporary excavations near 200 ft. O.D., at south end of Marquee Brow, junction with Colddean Belt, Stanmer Park, 250 yards west of Falmer Pumping Station. 66 NE.
389. Temporary excavations in Stanmer Park, above east side of road at Oldlodge Clump, on north side of parish boundary, SSE. of Stanmer Church. *Echinocorys scutatus* var. *elevatus* Brydone (typical form for low horizon of subzone). 53 SE.
390. West edge of Grubbings at top of field 120 yards west of Lot's Pond, quarter-mile NNE. of Stanmer Church, Stanmer Park, above the 400-foot contour. 53 SE.
391. Rabbit burrows inside Grubbings Plantation, 175 yards SW. of Lot's Pond, NE. of Stanmer Church, Stanmer Park, below 400 ft. O.D. Evidence indicated junction with zone of *Offaster pilula* at this spot. 53 SE.
392. South end of plantation (Wilkin's Folly), one-third mile SE. of mansion in Stanmer Park. 53 SE.
393. Uprooted tree at group of trees at 300 ft. O.D., 350 yards east of Stanmer Church, Stanmer Park. 53 SE.
394. Uprooted tree in centre of group of trees, 200 yards east of Lot's Pond, east of Grubbings Plantation, Stanmer Park. 53 SE.

395. About 50 yards north of middle (Westlain) Plantation, SSE. of old chalk pit with trees, 350 yards SSW. of Falmer Railway Station (near 250 ft. O.D.) 66 NE.

396. Edge of cultivated land about 60–70 yards south of middle (Westlain) Plantation, 500 yards south of Falmer Railway Station. 66 NE.

397. Cultivated land above 350 ft. O.D., between Westlain Plantation and 50 yards south, half-mile SW. of Falmer Church. Ossicles also obtained 60–75 yards south of Plantation, partly in subzone of *Uintacrinus*. 66 NE.

398. Edge of field on north side near 250 ft. O.D., east of lane to Balmer and about 200 yards NNW. of Upper Housedean Cottages, Falmer. Near top of zone. 53 SE.

399. Edge of field on west side at about 235 ft. O.D. (being northward extension of cultivated land contained in last item), 80 yards east of lane to Balmer and about 250 yards NNW. of Upper Housedean Cottages, Falmer. *Terebratulina rowei* Kitch. 53 SE.

400. Railway bank on south side near 200 ft. O.D., south of Housedean Farm, Falmer. *Terebratulina rowei* Kitch. 53 SE.

401. Railway section on north side south of west end of Upper Housedean Cottages, north of Cranedean Plantation, Falmer. 53 SE.

402. Edge of cultivated land on west side of hedge near 240 ft. O.D., half-mile NE. of Swan Inn, Falmer. 53 SE.

403. Evidence at about 230 ft. O.D., at SW. end of Long Hill, north of Lower Housedean Cottages and half-mile WNW. of Newmarket Inn, St. Ann Without, Lewes. 53 SE.

404. 200 ft. E.–W. temporary trench, west of Lewes Race Course, reaching above the 400-foot contour at east end, about 50 yards NW. of tumulus with triangulation spot, and 500 yards north of Ashcombe Plantation, St. Ann Without, Lewes. 53 SE.

405. Chalk dug for foundations for new Sun Insurance office buildings, 116–117 North Street, Brighton, at SW. corner of Queen's Square. Foundations about 20 ft. below surface. 66 SW.

406. Chalk, dug for foundations for Essoldo Theatre, North Street, Brighton, between Windsor Street and Portland Street. Foundations about 20 ft. below surface. Smooth plates of *Marsupites* obtained near bottom at Windsor Street end at about 50 ft. O.D. 66 SW.

407. Section on west side of road for about 100 yards at 300 ft. O.D. and above, from 50 to 150 yards SSE. of White Hawk (Camp), quarter-mile north of Manor Farm, Brighton. 66 SW.

408. Group of air-raid shelters above 200 ft. O.D., on east side of Wilson Avenue, 50 yards south of triangulation spot at north end of East Brighton Park, Brighton. *Terebratulina rowei* Kitch. 66 SW.

409. Temporary excavation on west side of B.R. near 350 ft. O.D., one-sixth mile east of Brighton Race Course and one mile NNW. of Ovingdean Church. 66 SE.

410. Temporary trench above 300 ft. O.D., about 200 yards NW. of triangulation spot on Mount Pleasant, Ovingdean. 66 SE.

411. Temporary trench above 300 ft. O.D., 150 yards NE. of triangulation spot on Mount Pleasant, Ovingdean. 66 SE.

412. Temporary trench just above the 200-foot contour in Ovingdean Road, 200 yards NE. of Ovingdean Hall, Ovingdean. 66 SE.

413. Chalk at NW. edge of cultivated field below 200 ft. O.D., on east side of Long Hill, Ovingdean, quarter-mile NW. of St. Mary's Home. 66 SE.

414. South bank of road, Westfield Avenue, Saltdean. 66 SE.

415. Temporary trench just above the 400-foot contour, NE. of triangulation spot, north of High Barn, High Hill, Rottingdean. 66 SE.

416. Bomb-crater above 200 ft. O.D., on north side of Coombe Bottom, one-third mile NW. of Upper Bannings and nearly one mile west of north end of Telscombe Village. 67 SW.

417. Temporary excavation at the south end of the 300-foot contour on Southease Hill on west side of parish boundary, one-third mile NE. of Telscombe Rectory. 67 SW.
418. Temporary excavation at 200-foot contour on escarpment on west side of parish boundary at west end of Bullock Down, 700 yards east of Telscombe Church. *Terebratulina rowei* Kitch. 67 SW.
419. North edge of field in valley, 200 yards west of Halcombe Farm, and one mile west of Courthouse Farm, Piddinghoe. 67 SW.
420. Cultivated land on south side of track on summit of Snap Hill, three-quarters mile NE. of South Heighton Church. 67 SE.
421. Pit on north side of footpath near spot 115, one-third mile SW. of Norton, and one-third mile NW. of Bishopstone Vicarage. 78 NE.

ZONE OF *OFFASTER PILULA*

422. Temporary trench at the 400-foot contour, 300 yards west of spot 429 on Dyke Road and nearly one mile NNE. of West Blatchington Church. *Offaster pilula* Lam. 65 NE.
423. Temporary trench at 400 ft. O.D., 150 yards NW. of last item. *Bourgueticrinus*, form 6, Brydone. Basement beds of zone. 65 NE.
424. Temporary excavation on east side of Dyke Road above 400 ft. O.D., 150 yards east of triangulation spot, half-mile NNW. of Red Hill Reservoir, Brighton. Low in zone. 65 NE.
425. Overgrown pit on east side of Dyke Road above 400 ft. O.D., quarter-mile NNW. of Red Hill Reservoir, Brighton. 65 NE.
426. Temporary excavation for drainage in new road on west side of overgrown chalk pit, above 300 ft. O.D., 150 yards west of Dyke Road Avenue at spot 360, three-quarters mile NNE. of Goldstone Water Works, Hove. Lower part of subzone of *Echinocorys scutatus* var. *cincta* to top of horizon of abundant *O. pilula*, just south of pit. 65 NE.
427. Bank of road near 200 ft. O.D. (Hill Drive, Hove), 100 yards west of Lower Tongdean, ENE. of West Blatchington Church. Horizon of *Hagenowia.* Belt of large *Echinocorys scutatus.* 65 NE.
428. Temporary drain trench in Goldstone Crescent, Hove, east of Hove Park at spot where road rises above the 150-foot contour, east of Goldstone Water Works, Hove. Horizon of *Hagenowia*. Upper Echinocorys scutatus Belt. 65 NE.
429. Temporary excavation for drainage in Dyke Close, west side of Dyke Road Avenue, 120 yards south of spot 360, quarter-mile north of Lower Tongdean, Hove. Horizon of *Hagenowia*. Upper Echinocorys scutatus Belt. 65 NE.
430. Temporary excavation at south end of Benett Drive (Bennett Drive on Six-inch Sheet), on north side of Woodruff Avenue, Hove. Small *Echinocorys scutatus* Leske including the var. *cincta* Brydone. Hagenowia Horizon. Upper belt of *Echinocorys scutatus.* 66 NW.
431. Temporary drain trench below south side of Colebrook Road, just above the 300-foot contour, 100 yards south of old chalk pit, half-mile west of Carden Avenue, Withdean, Brighton. Belt of *Echinocorys scutatus* var. *tectiformis* Brydone. Another trench in Colebrook Road yielded *E. scutatus* var. *depressa* Brydone. *Offaster pilula* Lam. was obtained 100 yards SW.of the old chalk pit. 66 NW.
432. Chalk exposed in bank above 100 ft. O.D., at SW. corner of cycle track, north end of Preston Park, and 100 yards east of St. Peter's Church, Preston, Brighton. Horizon of abundant *O. pilula* (upper belt). 66 NW.
433. Roadside section on east side of Ditchling Road at Old Boat Corner (junction with road to Cold Dean) and southward for about 50 yards, three-quarters mile west by south of Stanmer Church. North end of section in lower beds of the subzone of *E. scutatus* var. *depressa* yielding *Bourgueticrinus*, form 6, Brydone. South end yielded *E. scutatus* var. *truncata* Brydone, *Terebratulina rowei* Kitch, large *Serpula ilium* Sow. and *Offaster pilula* Lam. 53 SW.

434. Small pit in field above 400 ft. O.D., 150 yards east of Ditchling Road, 250 yards SSE. of Old Boat Corner and nearly three-quarters mile WSW. of Stanmer Church. Large *Serpula ilium* Sow. 53 SW.

435. West bank of Ditchling Road, 100 yards north of spot 461, five-sixths mile WSW. of mansion in Stanmer Park. Hagenowia Horizon. 53 SW.

436. Bomb-crater above 400 ft. O.D., 150 yards west of Ditchling Road (west of last item), one mile SW. of Stanmer Church. *Offaster pilula* Lam., large *Serpula ilium* Sow. and *Terebratulina rowei* Kitch. 53 SW.

437. Just inside south end of Great Wood at west end of Stanmer Park, a few feet above the 300-foot contour. *Bourgueticrinus*, form 1, Brydone and large *Serpula ilium* Sow. 66 NW.

438. Temporary excavation on spur outside east end of Great Wood, Stanmer Park, below 300 ft. O.D., 200 yards north of Marquee Brow. Subzone of *Echinocorys scutatus* var. *depressa* Brydone. 66 NE.

439. 30–75 yards south of top NE., end of cultivated land on west side of Upper Tenant Lain Drive, Stanmer Park, above the 300-foot contour, about two-thirds mile north of Falmer Railway Station. Belt with *Echinocorys scutatus* var. *truncata* Brydone. 53 SE.

440. Top of cultivated land on west side of Upper Tenant Lain Drive, Stanmer Park (above 300 ft. O.D.), between 200 and 300 yards south of north end of field. Horizon of abundant *Offaster pilula.* 53 SE.

441. Chalk dug for new fencing at track in Upper Tenant Lain Drive, Stanmer Park, also evidence to 25 ft. below track, about one-third mile NNW. of the Swan Inn, Falmer. Hagenowia Horizon. 53 SE.

442. Cultivated land near hedge, 200 yards NE. of Tenantlain Barn, Tenant Lain, Stanmer Park. *Bourgueticrinus*, form 1, Brydone and large *Crania egnabergensis* Retz. 53 SE.

443. Rabbit burrows on east side of Richmond Hill Plantation, Stanmer Park, 200 yards north of Russell's Clump, half-mile NNE. of Falmer Pumping Station (Waterworks). Large *Serpula ilium* Sow. 53 SE.

444. Temporary trench at south end of Grubbings Plantation, 280 yards south of Lot's Pond, quarter-mile ENE. of Stanmer Church, Stanmer Park. Subzone of *Echinocorys scutatus* var. *depressa* Brydone. 53 SE.

445. Uprooted tree inside south end of Grubbings Plantation, 250 yards south of Lot's Pond, quarter-mile ENE. of Stanmer Church, Stanmer Park. Subzone of *Echinocorys scutatus* var. *depressa* Brydone. 53 SE.

446. Temporary trench just north of plantation on Richmond Hill, Stanmer Park, 70 yards south of Grubbings Plantation. 53 SE.

447. Railway bank just beyond east end of south platform, Falmer Railway Station. 66 NE.

448. South bank of railway, 100 yards north of old pit with trees, 150 yards west of Falmer Railway Station. 66 NE.

449. Small overgrown pit by track, about 100 yards south of NE. end of Westlain Plantation, SSE. of Falmer Railway Station, near 350 ft. O.D. Hagenowia Horizon. 66 NE.

450. Chalk on cultivated land, west of east track, from old pit to 100 yards south of pit, 200 yards SW. of Falmer Railway Station. Large *Serpula ilium* Sow. 66 NE.

451. Chalk on cultivated land on west side of track, 150 yards west of old pit (with trees), 300 yards SW. of Falmer Railway Station. 66 NE.

452. Cultivated land, about 225 ft. O.D., 250 yards SE. of Falmer Pumping Station (Brighton Corporation Waterworks). 66 NE.

453. Chalk pit on west side of Ridge Road, just south of spot 366, one-sixth mile south of Ridge Farm and half-mile NNW. of the Swan Inn, Falmer. Large *Echinocorys scutatus* Leske, *Ostrea canaliculata* var. *striata* and *Hagenowia rostrata* Forbes. Near base of Hagenowia Horizon. 53 SE.

454. Chalk pit above 500 ft. O.D., on east side of Waterpit Hill, one-third mile NW. of Balmer, and one mile N. by E. of the Swan Inn, Falmer. Subzone of *Echinocorys scutatus* var. *depressa* Brydone. 53 SE.

455. Chalk on cultivated land, flat above 300 ft. O.D., 500 yards ENE. of the Swan Inn, Falmer. *Bourgueticrinus*, form 1, Brydone. 53 SE.

456. Chalk on cultivated land adjoining railway on north side, SSW. of Upper Housedean Cottages, north of Cranedean Plantation, Falmer. Low in zone. 53 SE.

457. Chalk dug for dew pond, above 300 ft. O.D., at east end of Long Hill, quarter-mile north of Newmarket Inn, St. Ann Without, Lewes. Upper beds of subzone of *Echinocorys scutatus* var. *depressa* Brydone. 53 SE.

458. Section cut in connection with electrification of railway, 150 yards east of cottage with B.M. 258.4, just over one-third mile east of the Swan Inn, Falmer. Belt of *Echinocorys scutatus* var. *truncata* Brydone. 53 SE.

459. Two specimens of *Offaster pilula* Lam. obtained in south bank of railway about half-mile east of the Swan Inn, Falmer. 53 SE.

460. Old pit in Cranedean Plantation, half-mile east of Falmer Church. *Hagenowia rostrata* Forbes (common). 66 NE.

461. Temporary excavation for camp purposes in field about 300 yards south of Falmer Church. *Echinocorys scutatus* var. *cincta* Brydone. Large *Serpula ilium* Sow. Near middle of zone. 66 NE.

462. Evidence of belt of *Echinocorys scutatus* var. *cincta* Brydone obtained on cultivated land above the 300-foot contour, east of Falmer Church, 180 yards east of old pit Cranedean Plantation, also 200 yards south of pit. 66 NE.

463. Temporary excavations for Brighton Corporation Waterworks Dept. above 400 ft. O.D., about 250 yards north of High Barn, High Hill, Rottingdean. *Offaster pilula* Lam. *Bourgueticrinus*, form 6, Brydone. 66 SE.

464. Temporary section above 200 ft. O.D., on south side of road at NE. corner of Long Hill, near entrance to Woodingdean House, nearly half-mile NE. of Ovingdean Church. Belt of *Echinocorys scutatus* var. *tectiformis* Brydone. Another exposure in the highest part of the road bank about 50 yards to the south-west, both sections being in the subzone of *Echinocorys scutatus* var. *depressa* Brydone. 66 SE.

465. Temporary trench at triangulation spot on Mount Pleasant, north of Ovingdean Church. *Offaster pilula* Lam. 66 SE.

466. Bank on east side of Quarry Road at top north end near 200 ft. O.D., east of Stanmer Avenue (Stanmore Avenue on Six-inch Sheet), south of Coombe Bottom, Saltdean. Belt of *Echinocorys scutatus* var. *tectiformis* Brydone. Section in bank at about middle of road in belt of *E. scutatus* var. *depressa* Brydone. 66 SE., 67 SW.

467. Overgrown pit, 150 yards north of Telscombe Road, Peacehaven, half-mile WSW. of Halcombe Farm, Piddinghoe. *Bourgueticrinus*, form 4, Brydone and *Retispinopora lancingensis* Gaster. Hagenowia Horizon. 67 SW.

468. Chalk pit at the 200-foot contour, 200 yards north of the Warren, west side of Telscombe Cliff Way, Telscombe. Hagenowia Horizon. Belt of large *Echinocorys*. 78 NW.

469. Chalk pit, 150 yards north of St. Peter's Avenue, Telscombe Cliffs, Telscombe. Hagenowia Horizon. 78 NW.

470. Overgrown pit just above the 100-foot contour, quarter-mile east of Lower Hoddern, Peacehaven. East end of pit yielded *Hagenowia rostrata* Forbes and *Retispinopora lancingensis* Gaster. 78 NW.

471. Depression in cultivated field on east side of Harbour Avenue, at about 200 ft. O.D., half-mile west of Meeching Quarry, Newhaven, Hagenowia Horizon. 78 NW.

472. Top of field on north side of main road near spot 148, one-third mile west of St. Michael's Church, Newhaven. Hagenowia Horizon. 78 NE.

473. Chalk on cultivated land at about 100 ft. O.D., on south side of Valley Road, one-third mile WNW. of St. Michael's Church, Newhaven; Horizon of abundant *Offaster pilula* Lam. 78 NE.

474. Chalk dug for N.F.S. tank about 50 yards east of old pit, one-sixth mile NNW. of Meeching Quarry, Newhaven. Large *Serpula ilium* Sow. 78 NE.

475. North bank of road on north side of the Rectory, Newhaven, about 80 yards west of church. 78 NE.

476. Section in meadow cut for defence works near 60 ft. O.D., quarter-mile SE. of Bishopstone Church. Belt of *Echinocorys scutatus* var. *tectiformis* Brydone. 78 NE.

477. Section in meadow cut for defence works near 75 ft. O.D., one-third mile SSE. of Bishopstone Church. Chalk yielded *Echinocorys scutatus* var. *depressa* Brydone. 78 NE.

478. Temporary excavations for foundations for new building (Mitre House) in Western Road, Brighton (between Hampton Place and Spring Street). Large *Serpula ilium* Sow. 66 SW.

479. Road excavation (17 ft. down) in middle of Regent Hill on north side of Western Road, Brighton, 150 yards SW. of St. Nicholas Church. 66 SW.

480. Temporary excavation on site for extension of Throat and Ear Hospital, Church Street, Brighton, 100 yards east of St. Nicholas Church. 66 SW.

481. Old pit, one-third mile west of Seaford Cemetery. *Bourgueticrinus*, form 1, Brydone. 79 NW.

481a. Exposure on shore by east end of the Parade, Seaford, west of Hawks Brow. *Hagenowia rostrata* Forbes and *Bourgueticrinus*, form 4, Brydone. 79 SW.

ZONE OF *ACTINOCAMAX QUADRATUS*

482. Road bank below north end of cottage garden, 170 yards NE. of West Blatchington Church. 65 NE.

483. By footpath above 100 ft. O.D., at west end of Hove Park, 150 yards east of Brighton and Hove Stadium, Hove. *Bicavea striata* Gaster. 65 NE.

484. Excavations for foundations for the King Alfred Buildings, south of St. Aubyns and east of R.N.V.R. Station, Kingsway, Hove. 65 SE.

85. Temporary section on east side of Shirley Drive, Hove, between Woodruff Avenue and Tredcroft Road. *Actinocamax quadratus* (Defr.) (2 specimens) and *Bicavea striata* Gaster. 66 NW.

86. Temporary trench in Tongdean Avenue, Hove, 250 yards west of Furze Court, west of Dyke Road Avenue, just below the 300-foot contour. *Bicavea striata* Gaster. 66 NW.

87. Temporary excavation near 200 ft. O.D., in Powis Square, Brighton, quarter-mile NW. of St. Nicholas Church. *Cidaris subvesiculosa* d'Orb. 66 SW.

88. Old chalk pit in plantation on west side of Ridge Road, 150 yards NW. of Old Forge Barn, just over quarter-mile north by west of the Swan Inn, Falmer. *Saccocoma cretacea* Bather. 53 SE.

89. Temporary excavation above north end of Chene Gap on east side, Friars Bay, Peacehaven. *Bicavea striata* Gaster and *Bourgueticrinus*, forms 4 and 7, Brydone. 78 NW.

90. Overgrown pit south of main road, just above the 100-foot contour on west side of Cavell Avenue, Peacehaven. *Bicavea striata* Gaster. 78 NW.

91. Edge of cliff, south of Dorothy Avenue, Peacehaven, 50 yards east of Greenwich Meridian, above 100 ft. O.D. *Bicavea striata* Gaster. 78 NW.

92. Overgrown pit, south of main road (partly enclosed in garden of house) between Gladys Avenue and Sun View Avenue, Peacehaven. 78 NW.

93. Overgrown pit south of main road between York Road and Cliff Road, Peacehaven, above 150 ft. O.D. 78 NW.

94. Pit above 100 ft. O.D., north of main road, 200 yards east of Cissbury Avenue, Peacehaven. Small *Crania egnabergensis* Retz. 78 NW.

95. Chalk on cultivated land by pit above 100 ft. O.D., north of main road, 200 yards west of Cissbury Avenue, Peacehaven. 78 NW.

96. Overgrown pit near Newhaven Golf Club House on north side of main road, Newhaven. 78 NW.

ACKNOWLEDGMENTS

Up to August 1943 the travelling expenses in connection with the field work were defrayed by the Government Grants Committee of the Royal Society. This is acknowledged with thanks.

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I am again indebted to my wife who has assisted me in the field and in many other ways during the progress of the work.

Finally, I have to record my gratitude to the landowners and others who have allowed me to enter on their lands or works for the purposes of geological investigations. These include the Southern Railway Company—now British Railways (Southern Region)—who always granted me the facilities needed to examine the sections on the sides of the railway cuttings; Viscount Gage who allowed me to enter Firle Park to ascertain the outcrop of the basement beds of the Chalk, and the Brighton Corporation (per the Borough Engineer and Surveyor) who granted me permission to enter Stanmer Park to secure evidence needed in connection with the broken structure of the 'Mount Caburn' syncline.

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THE ANNUAL REPORT OF THE COUNCIL OF THE GEOLOGISTS' ASSOCIATION FOR THE YEAR 1950

THE numerical strength of the Association on 31 December 1950, was as follows:

HonoraryMembers	19
Ordinary Members:	
Life Members (compounded)	170
Annual Subscibers	1751
	1940

During the year 209 new members were elected, and the Association lost 87 members through death, resignation and removals under Rule XI for failure to pay subscriptions. The membership continues to rise, and shows an increase of 126 over that of the previous year.

The list of deceased members is as follows: A. W. Breed, G. A. Browne, A. J. Bull, A. M. Champion, A. W. Cramp, F. L. Daniels, F. H. Dodd, S. N. Glass, W. T. Gordon, H. H. Gregory, J. Hargreaves, A. B. Hughes, H. J. Jeffery, W. Johnson, R. J. Leakey, J. M. Martyn, T. G. Morris, Miss E. F. Noel, R. H. Rastall, P. L. Walker, W. R. Watt and R. G. Wills.

Obituary notices will be found on pages 85–93.

FINANCE

On the Income side of the General Purposes Account admission fees and annual subscriptions show revenue of £936 10*s*. as compared with £850 10*s*. in 1949, £826 in 1948, and £714 in 1947. On the expenditure side of the Account, the cost of four parts of the PROCEEDINGS appears as £854 11*s*. 5*d*. as compared with £914 12*s*. 4*d*., the cost of the same number of parts in 1949. The cost of printing *Monthly Circulars* is, however, £177 8*s*. 2*d*. as compared with £130 3*s*. 3*d*. in 1949.

The balances in the various Special Funds, apart from the Reserve Fund for Index and List of Members, amount to £778 16*s*. 7*d*. This sum is available for the general purposes of the Association, and is in addition to the accumulated fund of £146 8*s*. 1*d*.

Unfortunately no grant from the Royal Society, as an allocation from the Parliamentary Grant in aid of Scientific Publications, has been received. In view, however, of the steady increase in membership, the general financial position of the Association does not appear to give rise to any immediate anxiety although serious consideration will have to be given to future policy.

Illustrations Fund

Contributions to this Fund amounted to £85 7*s*. 6*d*. from 145 members as compared with £61 3*s*. 8*d*. from 119 members in 1949 and £99 3*s*. 4*d*. from 123 members in 1948.

TRUST FUNDS

Foulerton Award Fund

An award of £10 has been made from this Fund and the balance remaining in the Fund at the end of the year was £22 9*s*. 10*d*.

G. W. Young Geological Investigation Fund

During the year a grant of £10 was made from the Fund to Mr. W. H. C. Ramsbottom in aid of a study of the Petalocrinus Limestone and its fauna in the Welsh Borderland. The balance in the Fund at the close of the year was £70 2*s*. 5*d*.

Henry Stopes Memorial Fund

A payment of £15 15*s*. from the Fund was made to Mr. S. Hazzledine Warren for the Henry Stopes Memorial Lecture. The balance of the Fund at the end of the year was £11 19*s*. 8*d*.

PUBLICATIONS

Publications Committee.—The Committee consisted of the officers (seven) together with Dr. S. Buchan, Mr. A. J. Butler, Dr. G. W. Himus, Mr. C. D. Ovey, Mr. G. S. Sweeting, and Mr. A. Wrigley. The Committee met on four occasions and considered twenty-six papers, upon which reports were made to the Council.

Proceedings.—It has been possible this year to issue all four parts (Vol. 61) within the year. The volume contains 306 pages.

MEETINGS

Nine Ordinary meetings were held at which two papers were read, three papers were read in abstract and six lectures were given, and attendances were well maintained.

The thanks of the Association are due to the Authors and Lecturers.

The meetings were held at the apartments of the Geological Society of London, and the Association's thanks are due to the authorities for the facilities afforded.

REUNION

The Annual Reunion was held at the Chelsea Polytechnic on Saturday, 4 November. Many interesting exhibits were shown and the attendance was well above the average. Thanks are due to the Principal and staff of the Polytechnic and the members concerned.

FIELD MEETINGS

The Committee consisted of the officers (seven) with Messrs. T. Barnard, E. E. S. Brown, F. H. Edmunds, G. W. Himus, J. F. Kirkaldy, C. D. Ovey, H. W. Pickworth, W. S. Pitcher, and M. K. Wells. During the year, due to the untimely death of Dr. A. J. Bull, Mr. H. A. Hayward (Field Meeting Secretary) was appointed Publications Secretary and Dr. T. Barnard appointed Field Meeting Secretary. In all, there were five demonstrations, two half-day, ten whole day, and the usual Easter, Whitsun, and Summer field meetings. A summer field meeting was also held in Norway. The average attendance at the field meetings was half-day twenty-five, whole day twenty-three, weekend twenty. Forty-three members attended the foreign field meeting. The demonstrations were well attended, over 170 members attending the demonstration held at Imperial College. Two whole day excursions were cancelled due to lack of support. The thanks of the Association are due to the directors and others, who organised and assisted at meetings. Considering the enlarged membership of the Association, attendance at field meetings was much lower than anticipated, especially when one takes into account that on many excursions the same regular attenders formed the bulk of the party, and the Council would very much like to see an increasing number of members availing themselves of the facilities offered by these excursions.

THE LIBRARY

The Library Committee consisted of the President, together with Dr. L. R. Cox, Dr. S. Buchan, Mr. R. V. Melville, Mr. G. S. Sweeting, Mr. R. Reeley, and Mr. J. Wilks, University College Librarian. The chief donation received was an extensive series of reprints of works by the late Professor M. Leriche, presented by Madame Leriche. Thanks are also due to the donors of a number of other books and pamphlets, listed in the PROCEEDINGS [p. 83]. The following overseas institutions have been added to the exchange list:

Amt für Bodenforschung (Hanover), Hessisches Landesamt für Bodenforschung, University of Coimbra.

The exchanges with the Istituto Geografico Militare (Florence) and the Royal Society of Arts, have been discontinued.

REPORT OF THE WEALD RESEARCH COMMITTEE

The death in April of Dr. A. J. Bull has been a sad loss, for he had been a most active Chairman, ever since the formation of the Committee in 1924.

Two reports have been published during the year: No. 41 by Professor S. W. Wooldridge on the structure and geomorphology of he Fernhurst area, Sussex; and No. 42 by R. Casey on the Gault–Lower Greensand junction in East Sussex and at Folkestone.

New work has been demonstrated at two Field Meetings; in the Ockley area, in Surrey, by W. H. E. Rivett and in the Fittleworth neighbourhood, Sussex, by D. W. Humphries.

NORTH-EAST LANCASHIRE GROUP

Chairman: J. Ranson, A.M.I.M.E., F.G.S.

Secretary: D. H. Learoyd, B.Sc., F.G.S.

Committee: Mrs. Harrop, B.A., B.Sc., W. Ashworth, F.G.S., F.R.G.S., J. E. Carter, M.A., F. Harding, M.Sc., J. E. W. Rhodes, Ph.D., B.Sc., F.I.C., S. Westhead.

During the year four lectures were given and three field meetings were held. Particulars will be published in the Report of the Session.

MIDLAND GROUP

Chairman: Professor F. W. Shotton, M.B.E., M.A., Sc.D., F.G.S.

Secretary and Treasurer: Miss Grace M. Bauer.

Committee: Professor L. J. Wills, M.A., Sc.D., F.G.S., F. B. Kelly, A. Bray, M.Sc., G. T. Warwick, M.B.E., B.Sc., F.R.G.S.

During the year five Meetings were held at the Geological Department, Birmingham University, and there were four Field Meetings. Particulars will be published in the Report of the Session.

Special thanks are due to Professor Shotton for the use of the Geology Department at the University for meetings.

NORTH STAFFORDSHIRE GROUP

Chairman: J. Myers, B.Sc., F.G.S.

Vice-Chairman: F. Wolverson Cope, D.Sc., F.G.S.

Secretary: T. S. Purcell, B.Sc.

Treasurer: Miss M. W. O'Malley, B.A.

Field Meeting Secretary: J. T. Gleaves, B.A.

Committee: W. J. Adams, A. M. Fairlie, T. T. Hinchin, B.A., J. C. Parrack, B.Sc., D. O. Thomas.

During the year eight meetings were held at the Arts Centre, Newcastle-under-Lyme, and there were three Field Meetings. Particulars will be found in the Report of the Session.

EAST MIDLAND GROUP

Chairman: A. D. Butterley, A.M.I.E.E., M.I.Min.E., F.G.S.

Secretary and Treasurer: G. J. Snowball, B.Sc., F.G.S.

During the foundation year of the Group one lecture was given and one field meeting held. Particulars will be published in the Report of the Session.

TRUSTEES

The Trustees of the Association are:

Managing: Mr. S. Hazzledine Warren, F.G.S., Dr. W. F. Fleet M.Sc., A.R.I.C., A.C.P., F.G.S., and Mr. E. C. Martin, O.B.E. B.Sc., A.R.I.C., F.G.S.

Custodian: The Royal Bank of Scotland, Western Branch.

FOULERTON AWARD

The Foulerton Award for the year was given to Mr. George Slater, D.Sc., D.I.C., A.R.C.S., for work of merit connected with the Association.

HOUSE LIST

Mr. E. C. Martin retires as senior Vice-President and Dr. S. L. Buchan, Professor David Williams and Mr. T. F. Grimsdale, as Ordinary Members of Council. Thanks are due to these members for services rendered to the Association, particularly to Mr. E. C. Martin, who has completed seventeen years continuous service on the Council.

Dr. K. S. Sandford retires from the Editorship and merits the thanks of the Association for service in that Office.

ACCOUNTS FOR THE YEAR ENDING 31 DECEMBER 1950

GENERAL PURPOSES ACCOUNT

INCOME

	£	s.	d.	£	s.	d.
To Admission Fees :						
Received for 1950 Elections	87	0	0			
Received for Arrears	13	10	0			
	100	10	0			
Less Arrears at 31 December 1949, £20 10, estimated to realise	12	0	0			
	88	10	0			
Add Arrears at 31 December 1950, £20 10, estimated to realise	12	0	0			
				100	10	0
To Annual Subscriptions :—						
(1) Received in 1944, 1947 and 1948 for 1950	4	0	0			
(2) Received in 1949 for 1950	85	0	0			
(3) Received in 1950 for 1950	656	0	0			
(4) Received in 1950 for arrears	46	0	0			
	791	0	0			
Less Arrears at 31 December 1949, £85 10, estimated to realise	35	0	0			
	756	0	0			
Add Arrears at 31 December 1950, £121, estimated to realise	80	0	0			
				836	0	0
To Sale of Publications				99	5	7
,, Miscellaneous receipts				3	9	3
,, Transfer from other Accounts :—						
From Illustrations Fund	100	0	0			
,, Compounding Fund	110	0	0			
,, Bequest Funds	100	0	0			
				310	0	0
				£1349	4	10

EXPENDITURE

	£	s.	d.	£	s.	d.
By PROCEEDINGS of the Association (Vol. 60, Part 4, and Vol. 61, Parts 1, 2 and 3) :—						
(1) Printing	671	19	8			
(2) Illustrations	151	9	6			
(3) Authors' separate copies	31	2	3			
				854	11	5
,, Printing Monthly Circulars				177	8	2
,, Stationery				59	4	10
,, Expenses at Meetings				36	5	6
,, Addressing and Stock-keeping				25	14	6
,, Postages				132	4	0
,, Insurance				1	16	0
,, Incidental Expenses				13	4	11
,, Yearly transfer to Reserve Fund for Index and List of Members				40	0	0
,, Excess of Income over Expenditure				8	15	6
				£1349	4	10

BALANCE SHEET, 31 DECEMBER 1950

LIABILITIES

	£	s.	d.	£	s.	d.
To Annual Subscriptions received in advance :—						
In 1944 for 1951		10	0			
In 1948 for 1951/54	2	10	0			
In 1949 for 1951/54	4	0	0			
In 1950 for 1951	87	10	0			
In 1950 for 1952/54	6	0	0	100	10	0
,, Sundry Creditors :						
Messrs. Benham & Co. Ltd.				31	7	10
,, Special Funds :						
Illustrations Fund	70	11	1			
Illustrations Fund (Capital)	20	0	0			
Reserve Fund for Index and List of Members	190	2	3			
Compounding Fund	1871	13	11			
Bequest Funds	761	18	2			
General Reserve Fund	329	0	0	3243	5	5
				3375	3	3
Accumulated Funds at 1 January 1950	137	12	7			
Add Excess of Income over Expenditure for the year	8	15	6	146	8	1
				£3521	11	4

ASSETS

	£	s.	d.	£	s.	d.
By Investments (Special Funds) at cost or value when acquired :—						
,, Bequest Funds—						
£143 8 9 3½% War Stock	141	14	0			
£150 New Zealand 3½% Stock, 1960/64 ...	122	5	0			
£285 3% Defence Bonds	285	0	0			
£100 3% Savings Bonds, 1960/70	100	0	0	648	19	0
,, Compounding Fund— ...						
£1217 2 6 Nottingham Corporation 3% Irredeemable Stock	1152	13	2			
£200 3% Savings Bonds, 1955/65	200	0	0			
£170 3½% War Stock	152	14	5			
£100 3% Savings Bonds, 1965/75	100	0	0	1605	7	7
,, Illustrations Fund (Capital)— £21 0 10 Metropolitan Water Board 3% B Stock				20	0	0
,, Annual Subscriptions in Arrears, £121, estimated to realise				80	0	0
,, Admission Fees in Arrears, £20 10s., estimated to realise				12	0	0
,, Cash at Bankers	57	14	6			
In Post Office Savings Bank	100	0	0			
In Office	28	11	5	186	5	11
,, Special Funds :						
Illustrations Fund at Bankers	70	11	1			
Compounding Fund at Bankers	266	6	4			
Reserve Fund for Index and List of Members at Bankers	190	2	3			
Bequest Funds at Bankers	112	19	2			
General Reserve Fund at Bankers	329	0	0	968	18	10
				£3521	11	4

SPECIAL ACCOUNTS

ILLUSTRATIONS FUND

	£	s.	d.
To Balance in hand on 1 January 1950	84	11	1
,, Donations and Subscriptions	85	7	6
,, Transfer from Illustrations Fund (Capital)		12	6
	£170	11	1

	£	s.	d.
By Transfer to General Purposes Account for Illustrations	100	0	0
,, Balance 31 December 1950, at Bankers	70	11	1
	£170	11	1

Special Accounts (*continued*)

ILLUSTRATIONS FUND (CAPITAL)

	£ s. d.		£ s. d.
To Balance in hand on 1 January 1950	0 0 0	By Transfer to Illustrations Fund	12 6
,, Dividends as received :—		,, Balance 31 December 1950	0 0 0
£21 0 10 Metropolitan Water Board 3% B Stock	12 6		
	£0 12 6		£0 12 6

COMPOUNDING FUND

	£ s. d.	£ s. d.		£ s. d.
To Balance in hand on 1 January 1950		262 16 6	By Transfer to General Purposes Account	110 0 0
,, Composition Fees received during the year... ...		62 0 8	,, Balance 31 December 1950, at Bankers	266 6 4
,, Dividends as received :—				
£1,217 2 6 Nottingham Corporation 3% Stock	36 10 2			
£170 3½% War Stock	5 19 0			
£300 3% Savings Bonds	9 0 0			
		51 9 2		
		£376 6 4		£376 6 4

RESERVE FUND FOR INDEX AND LIST OF MEMBERS

	£ s. d.		£ s. d.
To Balance in hand on 1 January 1950	150 2 3	By Balance 31 December 1950, at Bankers	190 2 3
,, Yearly Reservation for 1950	40 0 0		
	£190 2 3		£190 2 3

BEQUEST FUNDS

	£ s. d.	£ s. d.		£ s. d.
To Balance in hand on 1 January 1950		141 2 8	By Transfer to General Purposes Account	100 0 0
,, Dividends as received :—			,, Balance 31 December 1950, at Bankers	112 19 2
£143 8 9 3½% War Stock	5 0 6			
£150 New Zealand 3½% Stock	5 5 0			
£285 3% Defence Bonds	8 11 0			
£100 3% Savings Bonds, 1960/70	3 0 0			
		21 16 6		
,, Legacy in Herries will trust		50 0 0		
		£212 19 2		£212 19 2

GENERAL RESERVE FUND

	£ s. d.		£ s. d.
To Balance in hand on 1 January 1950	£329 0 0	By Balance 31 December 1950, at Bankers	£329 0 0

‘TRUST’ FUNDS

FOULERTON AWARD FUND

	£	s.	d.		£	s.	d.
To Balance in hand on 1 January 1950	22	0	2	By Award to Dr. George Slater	10	0	0
,, Dividends as received :				,, Balance 31 December 1950, at Bankers	22	9	10
£349 7 British Transport 3% Guaranteed Stock	5	15	2				
,, Income Tax repayment for 1949/50	4	14	6				
	£32	9	10		£32	9	10

G. W. YOUNG GEOLOGICAL INVESTIGATION FUND

	£	s.	d.		£	s.	d.
To Balance in hand on 1 January 1950	68	12	0	By Grant to W. H. C. Ramsbottom	10	0	0
,, Income for 1950, received from the Public Trustee...	7	11	8	,, Income Tax repayment paid to Public Trustee	3	15	10
,, Income Tax repayment for 1949/50	6	4	2	,, Balance 31 December 1950, at Bankers	70	2	5
,, Refund of Legacy Duty by Public Trustee	1	10	5				
	£83	18	3		£83	18	3

HENRY STOPES MEMORIAL FUND

	£	s.	d.		£	s.	d.
To Balance in hand on 1 January 1950	19	15	2	By Payment from fund to S. H. Warren, F.G.S.	15	15	0
,, Dividends as received :				,, Balance 31 December 1950 at Bankers	11	19	8
£265 19 2 Government of Newfoundland 3% Stock, 1943/63	4	7	10				
,, Income Tax repayment for 1949/50	3	11	8				
	£27	14	8		£27	14	8

We have compared these statements with the books and accounts presented to us and find them to agree.

We have also verified the investments of £1,217 2 6 Nottingham Corporation Stock, £200 3% Savings Bonds, 1955/65 £100 3% Savings Bonds, 1965/75, and, £170 3½% War Stock of the Compounding Fund, £349 7 0 British Transport 3% Guaranteed Stock, 1978/88, of the Foulerton Award Fund, £143 8 9 3½% War Stock, £150 New Zealand 3½% Stock, 1960/64, £285 3% Defence Bonds and £100 3% Savings Bonds, 1960/70, of the Bequest Funds ; £21 0 10 Metropolitan Water Board 3% B Stock of the Illustrations Fund (Capital), and £265 19 2 Government of Newfoundland 3% Stock, 1943/63, of the Henry Stopes Memorial Fund.

W. S. PITCHER
A. F. HALLIMOND } *Auditors*

R. W. POCOCK, D.Sc., F.G.S., *Treasurer.*

27 *January* 1951.

REPORT OF THE SESSION 1950

Ordinary Meeting, 6 *January* 1950.—Mr. E. Ernest S. Brown, M.B.E., F.G.S., President, in the chair.

Raymond Nicholas Brothers, Miss Josephine W. Cullen, B.A., Miss Margaret Sterndale Dilke, Miss Nancy Elizabeth Drew, Arthur Ellicott Dunning, John Moncur Jameson, Alexander Douglas Mitchell, Rowland Percy Moss, William Bennett Murphy, Miss Brenda Parnaby, Leslie Hartley Reid, Thomas Robey, Herbert David Rogers, Thomas Baird Smart, Howard Macmillan Stewart, John Gordon Stuart, Edward Trevor Stringer, B.Sc., Harry Thorpe, M.A., M.Litt., F.R.G.S., Bruce Wilcock were elected Members of the Association.

Mr. H. W. Pickworth and Mr. W. S. Pitcher were elected Auditors of the accounts for 1949.

The following lecture was delivered: 'Glimpses of the geology of Syria', by Francis Jones, T.D., M.Sc., Ph.D., F.G.S. and D. J. Shearman, B.Sc., F.G.S.

Ordinary Meeting, 3 *February* 1950.—Mr. E. Ernest S. Brown, M.B.E., F.G.S., President, in the chair.

Keith John Ackermann, Edward James Anderson, Arthur Burnet, F.R.A.S., Douglas Saxon Coombs, Horace William Dawkins, Richard Allen Downing, Miss Mary Alison Beattie Fotheringham, Harry Cecil Gabbitas, Philip Arthur Garrett, Joseph Newell Jennings, M.A., Ling-Chih Kuo, B.Sc., Miss Barbara Swanson McAdie, Miss Eunice Marsden, Frederick Arthur Edward Reeve, Mrs. Madeleine Rivett, William Westmoreland, B.A., Miss Jean Whitham, and Huai-Jen Yang, M.A. were elected Members of the Association.

The following lecture was delivered: 'Geological surveying in Southern Rhodesia', by B. Lightfoot, O.B.E., M.C., M.A., F.G.S.

Annual General Meeting, 10 *March* 1950.—Mr. E. Ernest S. Brown, M.B.E., F.G.S., President, in the chair.

The Annual Report of the Council (already circulated) was taken as read. It was moved by Mr. G. J. Snowball, seconded by Mr. T. W. Marsh, 'That the Report of the Council, including the Statement of Accounts, be adopted as the Annual Report of the Association for 1949'. The resolution was carried *nem. con.*

The President declared the following members duly elected as Officers and Members of Council in accordance with Rule XIII: President, T. Eastwood, A.R.C.S., M.I.M.M., F.G.S.; Vice-Presidents, E. C. Martin, O.B.E., B.Sc., A.R.I.C., F.G.S., A. Wrigley, G. W. Himus, Ph.D., F.G.S., A. G. Bell, I.S.O., B.Sc., F.G.S., E. Ernest S. Brown, M.B.E., F.G.S.; Treasurer, R. W. Pocock, D.Sc., F.G.S.; Secretaries, General—R. Reeley, F.G.S., Field Meetings, H. A. Hayward, O.B.E., F.G.S., Publications Committee—A. J. Bull, Ph.D., M.Sc., F.G.S.; Editor, K. S. Sandford, M.A., D.Sc., D.Phil., F.G.S.; Librarian, L. R. Cox, M.A., Sc.D., F.G.S.; twelve other Members of the Council, Miss M. A. Arber, M.A., F.G.S., F.R.G.S., T. Barnard, B.Sc., Ph.D., D.I.C., F.G.S., S. Buchan, B.Sc., Ph.D., F.G.S., A. J. Butler, O.B.E., M.Sc., F.G.S., W. Dack, I.S.O., F.G.S., T. F. Grimsdale, B.Sc., F.G.S., J. F. Kirkaldy, D.Sc., F.G.S., C. D. Ovey, B.Sc., F.G.S., H. W. Pickworth, F.R.M.S., Miss Mabel Tomlinson, B.A., D.Sc., Ph.D., F.G.S., D. Williams, M.Sc., Ph.D., B.E., F.G.S., C. W. Wright, M.A., F.G.S.

It was moved by Mr. S. E. Ellis, seconded by Mr. A. Burnet, and duly carried, 'That the best thanks of the Association be given to the retiring President, the Officers, retiring members of Council and the Auditors'.

Mr. Christopher T. A. Gaster, F.G.S. and Professor Olaf Holtedahl were elected Honorary Members of the Association.

The Foulerton Award was presented to Dr. George Slater, A.R.C.S., in recognition of work of merit connected with the Association.

The President said:

> Dr. George Slater, our PROCEEDINGS contain two important and valuable papers which you contributed on the glaciology of East Anglia. They are 'Glacial tectonics as reflected in disturbed drift deposits' (1926) and 'Studies in the drift deposits of the south-western part of Suffolk' (1927). These papers are outstanding for their detailed research and for the elaborate drawings of sections you provided to illustrate the disturbed deposits.
>
> Further, you conducted excursions of the Association to Ipswich in 1907 and 1911, to Cromer and Norwich in 1923 and again to the Ipswich district in 1938, when you demonstrated your studies at the sites which you had made historic in field research. At our Reunion in 1943 you exhibited scale drawings, sections and models of these remarkable deposits.
>
> Your late colleagues at the Imperial College of Science and Technology record your enthusiastic leadership of students in the field and your initiative and organising abilities in the teaching work of the College. It is from this source that for many years you introduced many new members to the Association and gave our work your whole-hearted support.
>
> In recognition, therefore, of your services to geology and to the Association the Council has conferred on you this year's Foulerton Award, and I have now much pleasure in presenting it to you.

The President then delivered his address entitled 'The story of quartz crystals'.

It was moved by Mr. S. Coomber, seconded by Miss E. Pyatt, and duly carried 'That the best thanks of the Association be accorded the President for his Address'.

Ordinary Meeting, 10 *March* 1950.—Mr. T. Eastwood, A.R.C.S., M.I.M.M., F.G.S., President, in the chair.

Mahmoud Ahmed Abdulla, Alan John Reath Bennett, William Walker Black, George Eveleigh Davies, Walter Ronald Edge, Royston William Dunlop Elwell, William Evans, John Michael Hancock, Stuart Arthur Harris, Murray John Hughes, D. Glynn Jones, M.Sc., F.G.S., Michael Lionel Charles Nicholls, Grahame Nowlan Rose, Cyril Penrose, M.Sc., F.G.S., Fred Rylance, B.Sc., M.I.M.E., A.I.M.M., F.G.S., Ernest Gordon Smith, Geoffrey Howard Smith, B.Sc., A.M.I.C.E., and Francis Edward Tocher, were elected Members of the Association.

Ordinary Meeting, 14 *April* 1950. Mr. T. Eastwood, A.R.C.S., M.I.M.M., F.G.S., President, in the chair.

Geoffrey Bennett Barnsley, Rowland Blyth-Palk, Donald Bramwell, Brian William Burton, Richard Osmer Drew, Anthony Francis Fox, James William Nicholson Hoseason, Gerald Graham Lemon, Mrs. Nellie Hooper Ludbrook, Dr. Alice F. A. Mutton, George Newell, A.R.I.B.A., A.M.I.Struct.E., Donald Harry Paddy, B.Sc., Walter Parnham, Roy Phillips, William Archer Robertson, Miss Cecilia T. U. Smith, John Wilfred Starling, Harvey Michael Sutcliff, Robert Claude Wilson, B.A., B.Sc., and William Edward Youngman were elected Members of the Association.

The following papers were read: (1) 'The tubular Chalk stacks of Sheringham', by T. P. Burnaby, B.A. (2) 'The junction of the Gault and Lower Greensand in East Sussex and at Folkestone, Kent', by R. Casey, F.G.S.

Ordinary Meeting, 5 *May* 1950.—Mr. T. Eastwood, A.R.C.S., M.I.M.M., F.G.S., President, in the chair

Derek John Angier, Robert Henry Hoare, Harold Stanley Jones, Richard Mackie, Cecil William Haviland Minchin, A.M.I.E.E., Assoc.I.Mech.E., John George Patrick, John Stanley Probert, Miss Ethel Mary Procter, Aidan Hector Robson, B.A., B.Sc., Alexander Puleston Terris, Frederick Lincoln Williams, and Brian Raymond Young were elected Members of the Association.

The second Henry Stopes Memorial Lecture entitled 'The Clacton flint industry: a new interpretation', was delivered by Mr. S. Hazzledine Warren, F.G.S.

Ordinary Meeting, 2 *June* 1950.—Mr. T. Eastwood, A.R.C.S., M.I.M.M., F.G.S., President, in the chair.

Miss Marian Anderton, Gerald Christopher Awre, B.Sc., Tom Harris Barneveld, Alistair John Boldero, Henry Platt Brown, Mrs. Gwendoline Brown, Basil Graham Burdett, Roger Philip Chandler, David William Edgerley, Stanley Hitchon, Henry Howard Vaughan Johnson, Mrs. Margaret Harrington Kerr, B.Sc., Miss Jean Barbara Laing, Peter Gibson Lazenby, Adrian James Lloyd, Peter Robin Lowe, Mrs. Lily McWilliam, William John Phillips, William Reginald Race, A.M.I.C.E., Miss Elizabeth Richards, M.Sc., F.G.S., Mrs. Margaret Helen Rule, Miss Marian Davies Tourelle, and Nikodem Welner were elected Members of the Association.

The following lecture was delivered: 'An outline of the geology of East Yorkshire which will be seen on the Summer Field Meeting', by Vernon Wilson, Ph.D., M.Sc. and C. W. Wright, M.A.

Ordinary Meeting, 7 *July* 1950.—Mr. T. Eastwood, A.R.C.S., M.I.M.M., F.G.S., President, in the chair.

Miss Joyce Marjorie Bond, Edwin Lloyd Brace, Norman Bannister Brown, Philip John Clarke, William George Curtin, Victor Douglas Dennison, Eric Archer Driver, Hugh Leonard Eastman, Rex Henry England, Ronald George Futcher, Ellis Wynn Griffiths, John Andrew Hale, Francis Leslie Jervis, Arthur William Keevil, Raymond William Alfred Knibbs, Richard St. John Lambert, Duncan McKie, Peter Harold Newton, W. Pickering, Ernest Arthur Feakes Robinson, Ernest Rowley, Alec James Smith, Charles Burton Tuerk, and Clarence Stephen Williams were elected Members of the Association.

The following lecture was delivered: 'The geochemistry of fluorine,' by K. C. Dunham, D.Sc., S.D., F.G.S., M.I.M.M.

Ordinary Meeting, 4 *November* 1950—Mr. T. Eastwood, A.R.C.S., M.I.M.M., F.G.S., President, in the chair.

Trevor Terence Bestow, Graham Cook, William Halliday Cooke, B.A., Norwood W. F. Greaves, Ian Lawrence McCallum, M.Inst. Mun.E., Miss Grace Annie McNeil, George Mueller, M.A., B.Sc., John Davis Thackwray, and Alexander George Walker were elected Members of the Association.

The Reunion which followed was held at the Chelsea Polytechnic and was attended by over 300 Members and friends. [For list of exhibits, see page 78.]

Ordinary Meeting, 1 *December* 1950.—Mr. T. Eastwood, A.R.C.S., M.I.M.M., F.G.S., President, in the chair.

Saad El Din Al-Ansary, B.Sc., Miss June Margaret Alexander, Noel Lionel Allport, F.R.I.C., Mahmoud Sayed Amin, Miss Joan Veronica Aucott, Christopher Norman Barron, Bryan Charles Betts, Leslie Arthur Bircumshaw, Kenneth William Bond, Donald John Burns, Ronald William Burrows, Roy Henry Butler, Hugh Cameron, James John Carr, Keith Martin Clayton, Robert Cleveland Connolly, Derek Ernest Coussell, Ian Alan Cowperthwaite, B.Sc., Arnold Edward Currall, Charles H. Dubras, Miss Mary Edith Duce, Miss Jeanne Dunn, Joseph Stanislaus Faulkner, Ian Hunter Forsyth, B.Sc., Jimoh Adisa Gbadamosi, George Warlters Greenwood, B.Sc., Thomas Bruce Hawthorn Hall, Geoffrey Harden, Ian F. Harrison, Ronald Keith Harrison, Paul Dighton Holness, Kenneth Hooper, Eric Reeday Illingworth, Frederick Dixon Jones, Miss Marjorie Kirkpatrick, Mrs. Patricia Knights, Mrs. Kathleen May Latham, Maurice Gordon Storrar Lepper, Donald Mackney, Alan John Martin, Gerald William Masse, George Arthur Matthews, David Grant Mortimer, Keith Hamilton Murray, Wilfred John Nowell, Keith Charles Overton, John Edward Owen, William John Clymo Pello, Lawrence Vaughan Penzer, Michael Albert Rogers, Andrew Theodore Vladimir Rothstein, William Alfred Saxton Salisbury, Frederick William Sherrell, Jeremy David Douglas Smith, Reginald

Arthur Smith, Miss Florence Edith Agnes Staffurth, Alan Stone, John Somerville Tooms, Miss Joan Elizabeth Tudman, Miss Mary Cameron Vogt, Donald Brian Vowles, Hugh Robert Watson, Ronald Albert Williams, Miss Grace Whitcroft, John Wymer, and Miss Patricia Joan Yates were elected Members of the Association.

The following lecture was delivered: 'The evaporites of North-East Yorkshire', by Professor S. E. Hollingworth, M.A., D.Sc.

LIST OF EXHIBITS

Geological Survey and Museum

(a) A selection from the Whitelaw Collection of Stained Agates.
(b) Some fossils from the Stowell Park Boring, Northleach, Gloucester.
(c) Geiger counters for use in prospecting for radio-active minerals.

British Museum (Natural History) Department of Geology

(a) *Proconsul*—Cast of the skull of an African Miocene ape.
(b) Restorations of fossil mammals drawn by Maurice Wilson.
(c) Reptilian bones from Ockley, Surrey.
(d) *Actinocamax* with phragmocone.
(e) *Xenusion*, a problematical organism, perhaps of late pre-Cambrian age.
(f) Production model of a parallel grinding instrument.

Arber, Miss Muriel A.

Illustrations of cliff profiles in Devon and Cornwall.

Bottley, E. P.

(a) Rare minerals from South America.
(b) Fine British and European minerals.
(c) Improvements in a student's goniometer.
(d) Field slide-making cabinet.
(e) New portable fluorescent lamp for use in the laboratory.

Carreck, J. M.

Non-marine Mollusca and other remains from some Quaternary deposits in the south of England.

Dollar, A. J.

Jan Mayen Structures.

Hayward, J. F.

Temporary geological exposures in the London area.

Higginbottom, J. E.

Specimens and photographs to illustrate the High Brooms *Equisetites lyelli* soil-bed.

Johnston, Miss Mary S.
The Association's Portrait Albums.

Kirkaldy, J. F. and Himus, G.
(a) Photographs and note books belonging to the late A. J. Bull.
(b) Press cuttings of the field meeting in Norway, August 1950.

Larman, M. L. and Smith, W. E.
Specimens collected on summer excursion to Norway.

Smethurst, Rev. Canon A. F.
Specimens of Chilmark Stone recently removed from the top of the spire of Salisbury Cathedral.

Stinton, F. C.
Eocene and Oligocene vertebrates.

Taylor, H. E.
Some vertebrate remains from London Clay of Bognor.

Venables, E. M. and Turner, J. G.
Lutetian fossils from the Nummulites laevigatus Bed of Bracklesham Bay.

Venables, E. M., Taylor, H. E. and Wrigley, A.
Some new light on the familiar London Clay Serpulid, *Rotularia bognoriensis* (Mantell).

Whitten, D.
Specimens collected by students of the Geology Department, Kingston-upon-Thames Technical College, during a summer field meeting in Scotland.

Whitten, E. H. T.
Specimens recently collected in Brazil.

Wilson, Gilbert
Photographs and drawings illustrating Mullion, Rodding and other lineation structures from the Moine Series.

Wright, C. W. and Wright, E. V.
Cretaceous fossils of Yorkshire to illustrate the Whitsun Field Meeting 1950.

FIELD MEETINGS

The following meetings took place:

Saturday, 21 *January*.—A demonstration was held at the Hydrographic Department of the Admiralty.

Saturday, 18 *February*.—By kind invitation of Professor J. A. Douglas, members were given the opportunity of visiting the new Geological and Mineralogical Department and the University Museum, Oxford. Over sixty members availed themselves of this opportunity.

Saturday, 11 *March*.—Demonstrations of palaeontological, petrological and mineralogical techniques were held in the Department of Geology and Mineralogy, British Museum (Natural History). This demonstration was extremely well attended.

Thursday, 6 *April to Monday*, 10 *April* (*Easter*).—The late Mr. H. H. Gregory conducted a party to the Charnwood Forest area.

Saturday, 22 *April*.—Under the leadership of Messrs. A. Wrigley and A. G. Bell, a large party spent an interesting afternoon studying the fossiliferous Blackheath beds at Elmstead Woods, Kent.

Saturday, 29 *April*.—Dr. T. Barnard led a half day excursion to study the lower London Tertiary beds in the neighbourhood of Oxshot and Claygate.

Saturday, 13 *May*.—Professor H. L. Hawkins conducted a party of over thirty members to study the geology of the Enborne Valley.

Saturday, 20 *May*.—A coach excursion under the direction of Professors S. W. Wooldridge and S. H. Beaver, enabled studies to be made of the sand and gravel deposits of West Middlesex, South Buckinghamshire and the Vale of St. Albans.

Friday, 26 *May to Monday*, 29 *May* (*Whitsun*).—Under the leadership of Mr. J. Myers, Dr. J. E. Prentice and Dr. F. W. Cope, an interesting and enjoyable weekend was spent studying the geology of North Staffordshire.

Saturday, 3 *June*.—Messrs I. E. Higginbottom and G. S. Sweeting conducted a party of twenty-four members to study the geology in the neighbourhood of Tonbridge, Tunbridge Wells and Burwash.

Sunday, 18 *June*.—Under the leadership of Mr. W. H. E. Rivett and Dr. J. F. Kirkaldy, exposures in the Weald Clay in the neighbourhood of Ockley were visited.

Sunday, 25 *June*.—Opportunity to study the geomorphological features in the Mole Gap, was offered by an excursion led by Mr. C. C. Fagg.

Saturday, 8 *July*.—Mr. D. W. Humphries led a party of eleven members on a strenuous but interesting excursion to Fittleworth, Sussex.

Sunday, 16 *July*.—Dr. G. W. Himus led a party of thirty-four members to the Hayes, Keston and West Wickham district.

Saturday, 22 *July to Saturday*, 5 *August* (*Summer*).—A Summer Meeting was held in East Yorkshire. From 23 July to 26 July, Dr. V. Wilson directed excursions to study the Middle and Upper Jurassic rocks. Under the directorship of Mr. C. W. Wright, excursions were held from 27 to 30 July to study the Cretaceous rocks of the coast and wolds. On Monday, 27 July the topography and superficial deposits of the Yorkshire Wolds were demonstrated by Dr. H. C. Versey, and on Tuesday, 1 August, Dr. H. C. Versey led an excursion to study the area in the vicinity of the Market Weighton Anticline. On Wednesday, 2 August, Dr. J. E. Hemingway, in inclement weather, demonstrated some of the glacial features of the Middle Jurassic beds of Goathland and Newtondale. In the afternoon Mr. McLaren entertained the party in the Museum at Whitby. On 3 and 4 August, Mr. W. S. Bisat demonstrated the older and newer drifts in East Yorkshire. On the whole the excursion was poorly attended, only six members being present at the end.

Sunday, 20 *August*.—A party of twenty-five members travelled by coach and spent an interesting day studying, under the leadership of Mr. R. V. Melville, the lower Greensand Sponge Gravels at Faringdon and the Corallian rocks in the neighbourhood of Oxford.

Saturday, 2 *September*.—Mr. S. W. Hester conducted an interesting half day meeting to study the relationship between the Lower Tertiary beds and the Upper Cretaceous in the Harefield district.

Sunday, 17 *September*.—A party of twenty-five members under the directorship of Drs. A. Morley and Vernon Wilson spent an enjoyable day in the Aylesbury and North Chiltern districts.

Saturday, 9 *December*.—Exhibits and demonstrations illustrating current researches were held at the Department of Geology, Imperial College (Royal School of Mines), South Kensington. Over 170 members availed themselves of this opportunity.

NORTH-EAST LANCASHIRE GROUP

The following Meetings and Field Meetings were held:

20 *January*.—Lecture, 'The geology of Glencoe', by W. B. McElvey, M.P.S. and J. Ransom, A.M.I.Min.E., F.G.S.

24 *February*.—Lecture, 'The rank of coal seams', by F. M. Trotter, D.Sc.

31 *March*.—Lecture, 'Paleolithic Art', by Miss E. McElroy.

28 *April*.—Lecture, 'The geology of Clitheroe', by S. Westhead.

20 *May*.—Field Meeting, 'The Pendleside succession'. Leader, S. Westhead.

17 *June*.—Field Meeting, 'The knolls of Little Bowland'. Leader, J. Ranson, A.M.I.Min.E., F.G.S.

9 *September*.—Field Meeting, 'The Sabden Shales and the Roach Bridge Unconformity'. Leader, D. H. Learoyd, B.Sc., F.G.S.

22 *October*.—Annual General Meeting, Lecture, 'Recent researches in glaciology', by D. H. Learoyd, B.Sc., F.G.S.

24 *November*.—Lecture, 'The non-marine lamellibranchs of the Coal Measures', by R. M. C. Eagar, B.A., Ph.D.

15 *December*.—Lecture, 'The Coal Measures of the Burnley Syncline', by A. Williamson.

MIDLAND GROUP

The following Meetings and Field Meetings were held during 1950:

21 *January*.—Exhibition of specimens by Professor F. W. Shotton, Messrs. E. D. Lacy, T. Nixon, G. T. Warwick, F. B. Kelly, A. Bray, A. Ludford, A. Strachan and P. A. Garrett.

4 *March*.—Lecture, 'The Millstone Grit of the Central Pennines', by G. H. Mitchell.

7 *May*.—Field Meeting: Kinver. Leader, Professor F. W. Shotton.

10 *June*.—Field Meeting: Lilleshall Hill. Leader, A. Bray.

8 *July*.—Field Meeting: The Lickey Hills. Leader, Professor L. J. Wills.

26 *August*.—Field Meeting: Clent, Worcester. Leader, A. J. Aiers.

28 *October*.—Lecture, 'British minerals other than coal', by T. Eastwood, A.R.C.S., M.I.M.M., F.G.S.

25 *November*.—Lecture, 'Impressions of Norwegian geology and geomorphology', by A. Ludford, M.Sc., F.G.S.

9 *December*.—Exhibition of slides, etc., by Professor Wills, Professor Shotton and Messrs. Parkinson, Ludford, Warwick, Bray, and Lacy.

NORTH STAFFORDSHIRE GROUP

12 *January*.—Ordinary Meeting: Demonstrations and Discussion.

9 *February*.—Lecture, 'The geological evolution of North Wales', by J. C. Parrack, B.Sc.

9 *March*.—Geological Brains Trust Session, Messrs. F. T. Jones, J. Myers, J. C. Parrack and T. S. Purcell.

27 *April*.—Annual Meeting: Chairman's Address, 'The amateur geologist', J. Myers, B.Sc., F.G.S.

11 *May*.—Lecture, 'The University of Birmingham Norway Expedition 1949', by G. T. Warwick, M.B.E., B.Sc.

10 *June*.—Excursion to view glacial overflow channels in Leek-Congleton area. Leader, J. C. Parrack, B.Sc.

2 *July*.—Excursion to Carboniferous Limestone of Manifold Valley, etc. Leader, Dr. J. E. Prentice.

12 *October*.—Opening Conversazione.

Talks: 'The North Staffordshire Coalfields', F. W. Cope, D.Sc., F.G.S. 'The polarising microscope', J. Myers, B.Sc., F.G.S. 'Demonstrations of micro-projection, D. O. Thomas.

Exhibition of maps, books, students' note books, specimens, with a series of petrological microscopes.

9 *November.*—Lecture, 'Speleological research', by W. Roy Midwinter.

14 *December.*—Lecture, 'The incombustible matter in coal', by A. H. Bray, M.Sc.

EAST MIDLAND GROUP

The following meetings were held:

4 *March.*—Lecture, 'The rôle of the amateur in geology', by Professor H. H. Swinnerton.

6 *May.*—Field Meeting: 'The Eakring Oilfield', Leaders, the Staff of the Anglo-Iranian Oil Company, and H. H. Gregory, M.A.

DONATIONS TO THE LIBRARY DURING 1950

(*The donors are the authors of the works presented, except where otherwise stated*)

ARBER, MURIEL A.—'Cliff profiles of Devon and Cornwall' (1949).

BIGOT, A.—'Description géologique du Col du Cotentin' (1948), and seven other pamphlets.

CAMBRIDGE, SGT. P.—'A succinct account of the lime rocks of Plymouth', by R. Hannah (1834), and eleven pamphlets by various authors.

COLE, SONIA M.—'An outline of the geology of Kenya' (1950).

COURTNAY, MARY I.—'The formation of the continents by convection', by G. F. S. Hills (1947).

DALY, R. A.—'Granite and metasomatism' (1949), and three other pamphlets.

DAVIS, A. G.—'Notes on Griffith's Maps of Ireland' (1950).

DOLLAR, A. T. J.—'Catalogue of Scottish earthquakes' (1950), and one other pamphlet.

ENNISKILLEN, THE RIGHT HON. THE EARL OF.—'Index Palaeontologicus', by H. G. Bronn, three vols. (1948-9); 'The Yorkshire Lias', by R. Tate and J. F. Blake (1876).

FAIRBRIDGE, R. W.—'Problems of Australian geotechnics' (1950), and four other pamphlets.

GEOLOGICAL SURVEY OF GREAT BRITAIN.—'Special Reports on the mineral resources of Great Britain. 35. The Limestones of Scotland' (1949). 'Geology of Central Ayrshire', second edition (1949).

GUILCHER, A.—'Nivation, cryoplanation et solifluxion quaternaires' (1950) and four other pamphlets.

HENSON, F. R. S.—'Cretaceous and Tertiary reef formation and associated sediments in the Middle East' (1950).

KHAN, M. H.—'Note on the depth and temperature of the Gault Sea as indicated by Foraminifera' (1950).

LERICHE, MADAME M.—A large series of reprints of monographs and papers by the late Professor M. Leriche.

QUEBEC, UNIVERSITÉ LAVAL.—'Le Musée de Minéralogie et de Géologie de l'Université Laval', by R. Bureau (1949), and one other pamphlet.

SWISS FEDERAL INSTITUTE OF TECHNOLOGY, ZURICH.—'Studies in photogeology', by R. Helbling, translated by N. E. Odell (1949).

TAINSH, H. R.—'Tertiary geology and principal oil fields of Burma' (1950).

UPSALA UNIVERSITY LIBRARY.—'On the Chamops Series of Femtland and Sødermanland', by P. Thorslund (1940); 'Rock composition and development in Central Roslagen, Sweden', by P. H. Lundegardh (1946).

UTRECHT, MINERALOGICAL AND GEOLOGICAL INSTITUTE OF THE UNIVERSITY.—'Smaller Foraminifera from Bodjonegoro', by L. Boomgart (1949), and sixteen other pamphlets.

WISEMAN, J. D. H. and OVEY, C. D.—'Recent investigations on the deep-sea floor' (1950).

OBITUARY NOTICES, 1950

ARTHUR MORTIMER CHAMPION died in Nairobi on 9 May 1950, at the age of sixty-five. Educated at Clifton College, he joined the Indian Army in 1905, but, after two years, sustained injuries from a riding accident which caused him to relinquish his commission. With the exception of serving with the R.F.A. in Europe during the years 1914–18 he was with the administration in Kenya from 1909 to 1935, when he retired. From 1931–5 he was Provincial Commissioner of Turkana Province and was awarded the C.M.G. on his retirement.

Much of his leave was spent in travelling, and his many interests led him to take every opportunity to observe the little-known country through which he travelled. He in this way collected much valuable geological material in the Province. His interests also included butterflies, birds and flowers, and for nearly forty years he was a member of the East African and Uganda Natural History Society and was finally president of it. In 1935 he joined the Association.

On his retirement he continued his explorations into obscure places with the aid of cinematography. In 1937 he crossed Africa from east to west and made a most interesting film, and in 1938 he accompanied the Lake Rukwa Expedition and assisted greatly in the survey and other work of the expedition. He also took a great interest in soil-erosion problems and published a number of works concerning the subject in Africa. In 1939 he was awarded the Founder's Medal of the Royal Geographical Society and in the same year received the Order of St. John and Jerusalem. In 1940 he was re-engaged by the Kenya Government and, with the aid of a van and mobile cinema, explained war news to the natives. He gave over 800 performances in four years to more than a million people.

He will be greatly missed both in East Africa and by his many friends in this country.

ALFRED WILLIAM CRAMP, who died on 12 July 1950, at the age of seventy-seven, joined the Association in 1919. An electrical engineer by profession, he received his training at the Northampton Institute and the Finsbury Technical College, where he came under the influence of Professor Sylvanus P. Thompson, for whom he always expressed the greatest respect and admiration. His scientific interests included geology, photography, microscopy and astronomy. An excellent craftsman, while still a young man he made his own camera and microscope, and the latter he used regularly to within a fortnight of his death. He also designed and made a machine for cutting rock sections which enabled him to form a large collection of microscope slides. He was an untiring collector of geological specimens and anybody interested in his stones was a welcome visitor in his home. He also delighted in drawing, watercolour painting and music, and in his earlier years often appeared on the concert platform as a solo violinist. Always eager to help the young, he had the satisfaction of starting several on scientific careers.

A.G.B.

FREDERICK LIONEL DANIELS died at his home at Rodborough, Stroud, on 10 March 1950, at the age of seventy-two. He was the third son of Joseph Daniels, owner of Lighthill Ironworks. His mother was a keen botanist, and, encouraged by his parents, he became interested in geology and decided at an early age to take up Mining Engineering. On the death of his uncle, however, he joined his father's firm, and later, with his two elder brothers, became managing director.

Mr. Daniels joined the Geologists' Association in 1900. He had many other interests and was a member of the Cotswold Naturalists' Association and the Bristol Naturalists' Club. He was instrumental in obtaining a room for the Stroud Museum of which Mr. C. J. Gardiner was the first curator.

During later years he became interested in local government and was elected chairman of the Stroud Urban Council for three terms of office.

He will be remembered by all those with whom he came in contact as an excellent organiser, a man of wide interests, and a kindly and helpful friend.

C.W.H.M.

FREDERICK HENRY DODD became interested in geology during the first world war. He gradually built up one of the finest private museums in the country. He inspired many to share in his hobby and at least three boys became successful mining engineers due to his influence. His medical career was largely concerned with children and he had a continuous relay of child curators to help in his museum. Throughout his life it was one of his joys to take parties of children for geological holidays. On his retirement in 1949 it became necessary to dispose of the bulk of his specimens, but he has left a small but much loved and carefully docketed collection.

L.W.G.

WILLIAM THOMAS GORDON, who died in London on 12 December 1950, after a brief illness, was an authority both on Carboniferous plants and on gemstones. Born in Glasgow on 27 January 1884, he was educated at George Heriots', Edinburgh, and at Edinburgh University. After graduating in 1906, he held Research Fellowships, first at Edinburgh and then at Emmanuel College, Cambridge. He returned to Edinburgh in 1910 as Lecturer in Palaeontology and in 1914 was appointed Lecturer in charge of the Geology Department at King's College, London. With the rapid expansion of the

Department after the first world war, he was promoted first to Reader and then, in 1921, to Professor. On his retirement in 1949, the University of London deservedly conferred upon him the title of Emeritus Professor.

Professor Gordon joined the Association in 1921, but prior to this he had conducted day excursions to Bathgate and to Kirkcaldy, Kinghorn and Burntisland, during the Long Excursions to East Scotland in 1912 and to the Edinburgh district in 1913. When the Association next visited Edinburgh in 1927, he demonstrated the sections near North Berwick, from which he had obtained a wealth of beautifully preserved Lower Carboniferous plants. This material he worked out with great thoroughness; the publication of his results, mainly in the *Transactions* of the Royal Society of Edinburgh, of which he was a Fellow, being spread over more than thirty years. For this work he was awarded the D.Sc. degree of the University of Edinburgh in 1911, the Lyell Fund of the Geological Society in 1913, and the Makdougall-Brisbane Medal of the Royal Society of Edinburgh in 1922. He was interested in all aspects of palaeobotany, and, when President of Section C (Geology) of the British Association at the Aberdeen Meeting in 1934, he chose as the subject of his address 'Plant life and the philosophy of geology'.

In his gemmological interests he was following in the tradition of one of his predecessors in the Chair at King's College, Professor James Tennant, the third President of the Association. Professor Gordon made a special study of diamonds and was frequently consulted by the industry and others. When the Association visited the Geological Department, King's College, in 1921, 1935 and 1938, the exhibits of gemstones from his extensive private collection aroused much interest. In 1944 the Annual Reunion was held at the College, and the Professor contributed a particularly interesting exhibit, illustrating both the crystallography and the industrial uses of diamonds.

He was a great believer in geologists seeing as much of the world as possible and he himself travelled widely. Several times he exhibited at our Conversaziones specimens which he had collected during his travels, and in 1925 he delivered a lecture on the Geology of the Yellowstone Park. Members who were with him on the Long Field Meetings to Czechoslovakia, Torquay, North Devon and elsewhere, will recall his great assiduity and skill in collecting and the certainty with which he identified difficult material, using his well-known hand-lens mounted at one end of his pocket-knife.

Professor Gordon will be remembered for his personal qualities with affection, not only by many members of the Association, but especially by the considerable body of his old students. He was always the best of company and was ever ready to listen to the difficulties of others and to tender advice. Much of his time, in his later years, was spent in serving on a wide range of committees.

This is not the place to enlarge on the devoted service that he gave to many bodies concerned with the well-being of the students of the University of London, but in the geological world he served on the Council of the Association from 1926–8 and was a Vice-President from 1928–30, whilst he was a Secretary of the Geological Society from 1929–37, as well as being keenly interested in the Mineralogical, Linnean, and Photomicrographic Societies.

Perhaps the outstanding memory he has left was his lively and friendly interest in the travels and work of all those with whom he came in contact. There can be no question that his own research work suffered by the amount of time he gave up to helping others, but he was willing that it should be so.

J.F.K.

HUBERT HAROLD GREGORY came from, and belonged to, the Nottinghamshire–Derbyshire borders. Educated at Sutton-in-Ashfield and Hucknall Secondary Schools, he proceeded to University College, Nottingham, and thence to Reading, where he commenced a Diploma Course in Geography. Early in 1915 he joined the R.N.V.R. and, later in the war, served as a gunnery officer in the Dover and Harwich Patrols. After the Armistice he was with the Allied Naval Commission in Germany. On demobilisation he completed the Diploma at Reading and then entered Wadham as a commoner. At Oxford his geographical studies were continued but under the influence of Professor Sollas he took up geology. He took his B.A. in 1923, and in the same year was appointed Assistant Curator at Leicester Museum and Art Gallery, then under the able direction of Dr. E. E. Lowe. There are 'live' museums and 'dead' museums: Leicester possessed a very 'live' one and the acquisition of Gregory increased its vitality. The late Professor W. W. Watts had endowed the local amateurs with a goodly portion of his spirit, counsel and understanding. Among these Dr. F. W. Bennett was the leader who guided the Museum Committee, and geology thrived. Bennett captured Gregory for Charnwood in 1923 and it is safe to say that, in due time, the recruit knew that fascinating area as well as Watts himself. Gregory never let himself become a mere 'pre-Cambrian' petrologist; his Oxford training had thrown wide the gates; he was equally at home on the Jurassic or 'glacial'. Before illness overtook him, he was physically tough; where Gregory went, a 14 lb. sledge hammer went too, that is, if he were not sure of a 28 lb. or 56 lb. quarry weapon being available. He became leader of what might be called the 'Leicester School of Collecting'. The Museum did not accept or harbour indifferent material and would have consigned most of the specimens gathered to illustrate 'research' to their fit and proper destination—road metal. This was not just a matter of collecting for display but an insistence of getting to the heart of a rock, followed by rapid and skilful trimming to make samples 'presentable'.

Gregory had no use for slovenly specimens: to him they meant slovenly geology.

Although at his best out of doors, he was delightful in his museum surroundings; there was no need for welcome on his door-mat, he emanated good humour. There, in addition to geology, he answered, or parried, queries in zoology, ethnology, local history, and even hosiery machinery: he liked making wheels go round and playing with gadgets, new and old. He became a member of the Geologists' Association in 1923 and from that year until his death was a very active member, joining many excursions and leading not a few. He acted as director of Field Meetings in Charnwood in 1928 and 1937—on the latter occasion his co-director was W. W. Watts—and only last Easter he took the Association once more to the same locality. He acted as local secretary to Section C, British Association, and was editor of their report in 1933. His share in the 'Geology of Charnwood Forest' (published by the Geologists' Association) was very large. Most of the photographs, including the microscope slide studies, were his work. He published little; a few short papers in the *Transactions of the Leicester Literary and Philosophical Society* and a 'Geology of the Leicester District', written for the Regional Planners, constitute all. He left the Museum to join the staff of Town and Country Planning two years before his death.

In addition to his main occupation Gregory acted as Lecturer in Geology (Extra Mural Studies) at University College, Leicester. He gathered round him an enthusiastic band of adult students who will continue his work. He enjoyed geology and his infectious native humour made all his followers good companions. His death, at the comparatively early age of fifty-five, leaves the Association and geology the poorer.

F.J.

JAMES HARGREAVES. By the death of James Hargreaves, a well-known figure has been removed from natural history circles in Bacup and East Lancashire. Mr. Hargreaves was one of Rossendale's stalwarts who had done much to foster the love of geology and antiquities during the past fifty years. Of recent years he had been the continuous president of the Bacup National History Society, and he was also a devoted member of the North-East Lancashire Naturalists Union. In spite of his advanced years and failing health, he remained active to the last and will be sadly missed.

J.R.

ALWYN BERWYN HUGHES died at his home, Bryntirion, near Bala, 23 May 1950, in his eighty-fifth year. Born in Liverpool of Welsh parentage, he was educated at the Liverpool Institute, and afterwards entered the service of Thos. and James Brocklebank Ltd., Shipowners, with whom he spent his business career, holding the position of managing director at the time of his retirement. He took a deep interest in education, and for a long period gave valuable service as a school manager under the Liverpool Education Committee, and he was always ready to encourage and assist young students. His interest in geology was keen and enthusiastic, although he never undertook original work. He joined the Association in 1924 and attended many of the Easter week-end excursions. He was also a senior member and generous supporter of the Liverpool Geological Society. Geology, however, was not his only hobby. He had a deep love of literature, and was a member of the Cambrian Archaeological Association and a Fellow of the Royal Horticultural Society. About two years before his death he purchased a small estate, Bryntirion, about two miles from Bala, on the hillside above the south-east bank of the lake—a district to which he was strongly attached. Here he settled in the spring of 1948, and spent two happy and busy years carrying out improvements to his property, and studying the natural history and antiquities of the area. He had two sons, and the untimely death of the younger in December 1949 saddened the last few months of his life.

T.A.J.

Henry John Jeffery died at his home at Peacehaven, Sussex, on 24 July 1950, aged sixty-five years. He was educated in London and trained in horticulture at the School of Gardening of the Royal Botanical Society, Regent's Park. He became a student at Birkbeck College, University of London, and obtained a National Scholarship in geology at the Royal College of Science, where, however, he decided to devote himself to botany. In this subject he won a First Class Associateship of the College in 1907. He was lecturer in botany both at the School of Pharmacy, Pharmaceutical Society, Bloomsbury, and at the Southwestern Polytechnic, Chelsea, during the period 1907–11. He joined the Association in 1907.

He entered the Scientific and Technical Department of the Imperial Institute, South Kensington, in 1911, as Special Assistant in the preparation of the *Bulletin of the Imperial Institute* and other official publications, and later became in charge of the Institute's library. In 1926 he was transferred to the Intelligence Section of the Plant and Animal Products Department of which he became Vice-Principal in 1936 and, in due course, editor of the *Bulletin*. After serving thirty-three years at the Imperial Institute he retired in 1944.

He was a Fellow of the Linnean Society and a member of the London Natural History Society. He was joint author with J. F. Bevis of 'British Plants: their biology and ecology' (1911; 2nd ed. 1920). On his retirement he went to live at Peacehaven where he took up the study of British Coleoptera; here he also assisted in the organisation of the local sports clubs.

WALTER JOHNSON was born in 1867 at Saltfleetby in north Lincolnshire. After spending two years at St. Paul's College, Cheltenham, he entered the service of the School Board for London, teaching for two years in Peckham and, later, in Battersea until his retirement. As a naturalist, antiquary and geologist he found congenial spirits in G. W. Young, William Wright, B. C. Polkinghorne, P. McIntyre, G. E. Dibley, A. W. Rowe, A. J. Maslen and others who were, or became, active members, if not officers, of this Association. With Young and Wright he studied the Chalk of the North Downs; with Rowe and Dibley he examined the coastal exposures from Folkestone to Sidmouth. He was elected a Fellow of the Geological Society in 1906 and joined this Association in the following year. His field-work extended to the flint implements and other archaeological relics of the Downs, the Thames valley and other areas at home and abroad.

From the common interests and genial helpfulness of his early friends arose the Battersea Field Club. Formed in 1905 it prospered for many years until, in 1944, difficulties caused by the Second World War brought to Johnson, the last surviving founder-member, the melancholy duty of winding-up its affairs.

To Johnson, who took almost every aspect of the countryside under his eye, the natural features and human geography of every heath and hill in Surrey must have been familiar. He was equally at home in the British Museum and other libraries; and much of the curious lore which he acquired within and out-of-doors went into his books.

'Neolithic Man in N.E. Surrey' (1903), written in conjunction with William Wright as also 'Folk memory' (1908)—the invented title has passed into the vocabulary of archaeology—and again 'Byways in British archaeology' (1912), all included research in the borderland of geology and archaeology. 'Talks with shepherds' (1925) compares well in style and substance with W. H. Hudson's works. He contributed to the *Academy*, the *Naturalist*, the *Transactions* of the London and Middlesex Society, wrote 'Wimbledon Common' (1912), 'Gilbert White, pioneer, poet and stylist' (1928), edited Gilbert White's 'Journals' and prepared Henry White's 'Log-Books' which, however, as also his last work 'Ice and Man in Lincolnshire', remains unpublished.

After his wife's death Johnson lived near Chatham where, as member and President of the Rochester Naturalists' Society, he continued his open-air pursuits until he moved into Cornwall to be near his daughter at St. Austell, where he died on 18 November 1950, aged eighty-three years. His death ended a friendship of sixty years during which I had never seen his even temperament disturbed and had many opportunities of observing his great, if quiet, enjoyment of life, especially among the sights and sounds of the English countryside.

A.I.L.

Thomas Glynn Morris died on 1 January 1950, at his home, Basil Grange, Sandfield Park, West Derby, Liverpool, after a long illness. He was born at his mother's old home, Caernant, Llanfaelog, Anglesey, on 16 April 1869, but his parents were then living in Liverpool. After completing his medical training at University College, Liverpool, where he took the degrees of M.B., Ch.B., Vict. in 1890, and subsequently the degree of M.D. at Liverpool University in 1918, he spent some years among the quarrymen at the Nantlle Vale Slate quarries, Caernarvonshire, and then came to Liverpool, on the death of his uncle, to take on his large practice in Everton. He continued in practice for forty-five years, latterly in partnership with his elder son. He was elected a member of the Association in 1926 and frequently attended its long excursions, and for some years was also a Fellow of the Geological Society of London. He was an active member of the Liverpool Geological Society of which he was president in 1938 and 1939, and was a generous supporter of all its work and always ready to extend hospitality to visiting geologists. Archaeology and antiquities also had a great attraction for him, and he was a member of the Cambrian Archaeological Association and a Fellow of the Royal Geographical Society.

T.A.J.

William Robert Watt. It is with regret that we announce the death of Mr. William Robert Watt, at Kanpur, U.P., India, on 11 September last.

Mr. Watt was born just over sixty years ago in the north of Scotland, where he received his early schooling. In due course he proceeded to Aberdeen University, where he had a distinguished academic career. Thereafter, chemistry and geology attracted his attention, but in the year 1913 he was tempted to accept an offer of employment in India, and in that year joined the staff of the Cawnpore Woollen Mills Company, a firm to become, in 1920, one of the manufacturing units which amalgamated to form the British India Corporation Ltd. Mr. Watt was eventually appointed Manager of the Cawnpore Woollen Mills, and in 1937 became the British India Corporation's Woollen Superintendent, in which capacity he supervised not only the Cawnpore Woollen Mills, but the Corporation's other Woollen Unit, the New Egerton Woollen Mills at Dhariwal in the Punjab. In 1940 he was invited by the Government of India to be their Honorary Adviser for the Woollen Industry. These duties he carried out during the whole of the war, being awarded the C.B.E. for his services in 1942. At the beginning of the war, Mr. Watt was appointed a Director of the British India Corporation, and later was appointed first as a Deputy Managing Director of the Corporation and later as Vice-Chairman of Directors.

It can truly be said that he died in harness, because, in the absence of the Chairman of Directors, he presided over a Meeting of

Directors just a week before he died, and on that same afternoon was taken ill, and to the great grief of very many friends, did not recover. He is survived by his widow and one son.

ROBERT GLOVER WILLS died at his home, Northgate, Blundellsands, near Liverpool, on 15 February 1950, after an illness which had incapacitated him for nearly two years. Born in Bootle in 1878, he was the eldest son of Dr. Thomas Munns Wills, a well-known physician, who had a large practice in that borough, and he received his early education in schools in Canterbury and Oxford. Afterwards he went to St. John's College, Cambridge, where he gained a second class in the Natural Sciences Tripos 1900. He proceeded to the M.A. degree in 1905, and also obtained the M.B. and B.C. degrees in the same year having already qualified as M.R.C.S. and L.R.C.P. With his private practice he combined the office of honorary physician of the Booth General Hospital. He was a member of the Liverpool Medical Institution of which he was president in 1942, and for a time honorary librarian. He joined the Association in 1921 and took part in many of its excursions. He was a valued member and past president of the Liverpool Geological Society, and his two presidential addresses on 'The contribution of British medical men to the foundation of geology' and 'Some effects of meteorites' are printed in its *Proceedings* (Volumes 16 and 17), as well as a paper on 'Bacteria from the geological aspect' (Volume 13).

A man of many and diverse interests, all of which he pursued with characteristic pertinacity and thoroughness, he was a member of the Swiss Alpine Club, and an eager student of natural history and philately. He was a bachelor and lived with his two sisters.

T.A.J.

THE ZONAL POSITION OF THE GAULT-LOWER GREENSAND JUNCTION BEDS AT WRECCLESHAM, SURREY[1]

By R. CASEY, F.G.S.

(*Weald Research Committee Report No.* 43)

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SUMMARY.—Re-opening of old workings at Wrecclesham, Surrey, has permitted a detailed examination of the beds at the junction of the Gault and Lower Greensand and has led to the discovery of a highly interesting ammonite fauna, assignable to horizons within the Tardefurcata Zone (Lower Albian) and the Mammillatum Zone (Middle Albian). This provides the first record of the Tardefurcata Zone in Surrey.

PITS showing the junction of the Gault and Lower Greensand have been worked intermittently at the village of Wrecclesham (formerly Wracklesham), near Farnham, Surrey, for well over a century. They were mentioned by Murchison as early as 1826 (1826, p. 100) and were fully described in 1848 by Paine and Way (1848, p. 78). A section of the beds exposed near Wrecclesham Church was measured by Drew (1875, p. 142) and his description of the section is quoted by Jukes-Browne (1900, pp. 96–7) and by Dines (1929, p. 40). No original observations have been made on the beds, however, since 1893, when the pits were visited by the Geologists' Association under the leadership of H. W. Monckton and H. A. Mangles (1893, pp. 76–7).

As seen by Paine and Way, and by Drew, the section showed about fifteen feet of clayey sands with three seams of phosphatic nodules, the beds forming a gradual passage upwards from the sandy Folkestone Beds of the Lower Greensand to the blue clays of the Gault. From the middle seam of phosphatic nodules Monckton and Mangles recorded a number of fossils, including *Ammonites beudanti* and *A. interruptus.* In discussing the correlation of the section Monckton and Mangles expressed doubt as to whether the beds should be referred to the Dentatus [Interruptus] Zone or to the Mammillatum Zone. The subsequent discovery by Monckton of *Douvilleiceras mammillatum* in the same fossiliferous seam is mentioned by Jukes-Browne, who appears to have been induced thereby to refer all three phosphate beds at Wrecclesham to the Mammillatum Zone (Jukes-Browne, A. J., 1900, pp. 96–7). Certain sandy beds at the base of the Gault in the Alresford district of Hampshire have since been assigned to the Mammillatum Zone by Osborne White chiefly on the grounds that lithologically they resemble the beds at Wrecclesham (White, H. J. O., 1910, p. 17).

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[1] Published with the permission of the Director of the Geological Survey and Museum.

In the present note it is shown that in addition to the Middle Albian Mammillatum Zone, the Tardefurcata Zone of the Lower Albian is also represented in the Gault–Lower Greensand junction-beds at Wrecclesham. Strata of Tardefurcata age have been identified in England only at a few isolated localities and have not been reported previously from Surrey.

During the re-survey of the Wrecclesham area by the Geological Survey in 1926, the pits were obscured, but a section similar to that described by Drew was seen at Clay Hill, about half a mile south-west of Wrecclesham Church, and yielded fossils of the Mammillatum Zone (Dines, H. G., 1929, p. 41). In 1945 a further section was examined by the writer in an excavation by the roadside adjacent to the southern precincts of Wrecclesham Church, and also in an old degraded pit about another fifty yards to the south-west. The westerly extension of new workings in the Folkestone Beds has since led to the re-opening of this pit, permitting the succession to be studied in detail. The section given below (Table 1) was demonstrated to the Geologists' Association in July 1949.

TABLE 1.—SECTION OF THE GAULT–LOWER GREENSAND JUNCTION-BEDS ABOUT 50 YARDS S.W. OF WRECCLESHAM CHURCH.

			ft.	in.
		Flint drift		
Mammillatum Zone	? Inaequinodum Subzone	13. Blue, somewhat sandy clay	3	0
		12. Mixture of blue clay and sand with scattered phosphatic nodules	2	6
	Monile Subzone	11. As 12, but sandier and with fewer nodules	1	6
		10. Seam of whitish phosphatic nodules...		3–6
		9. Grey clayey sand with thinly scattered phosphatic nodules		9
		8. Buff sand	1	6
		7. Grey clayey sand	1	0
		6. Coarse buff sand		9
Tardefurcata Zone	Regularis Subzone	5. Grey phosphatic nodules in an ill-graded matrix of coarse buff sand and grey clay		2–4
		4. Coarse clayey sand with sparse phosphatic nodules	3	6
		3. Impersistent seam of soft brick-red sand		6–12
		2. Coarse buff sand with occasional friable phosphatic nodules	4	0
	?Acuticostata Subzone	1. Coarse buff sand, streaky iron-staining, small-scale current-bedding, some carstone near the base ... ... about	40 seen	
		Total about ...	60	0

The palaeontological evidence on which the zonal classification of the section is based is given in the accompanying table (Table 2). The three main concentrations of phosphatic nodules described by arlier authors are Beds 5, 10 and 12 of the present section. Of these ed 10 is the principal source of fossils, yielding a large fauna of amellibranchia and other groups in addition to the Ammonoidea ere recorded. This bed, together with its substratum (Bed 9), falls ithin the Monile Subzone of the Mammillatum Zone, which has an lmost continuous outcrop around the Wealden anticlinorium. It is quivalent to the Main Mammillatum Bed of the classic Albian ection at Copt Point, Folkestone. The '*A. Beudantii*' recorded from his bed by Monckton and Mangles (1893, p. 76) almost certainly efers to *Beudanticeras ligatum*, ubiquitous on this horizon: the *A. nterruptus* of the same authors was probably a species of *Protohoplites*.

ABLE 2.—AMMONOIDEA FROM THE GAULT–LOWER GREENSAND JUNCTION BEDS ABOUT 50 YARDS S.W. OF WRECCLESHAM CHURCH.

	Beds					
ictetia depressa (Pictet)	–	–	5	–	–	–
eudanticeras ligatum (Newton and Jukes-Browne)	–	–	–	9	10	–
,, *dupinianum* (d'Orbigny)	–	–	–	–	10	–
ouvilleiceras mammillatum (Schloth.)	–	–	–	9	10	–
,, ,, var. *baylei* Spath ...	–	–	–	–	10	–
,, *monile* (J. Sow.)	–	–	–	–	10	–
eymeriella tardefurcata (Leymerie) d'Orbigny sp.	–	–	5	–	–	–
,, aff. ,, ...	–	4	–	–	–	–
,, *intermedia* Spath	–	–	5	–	–	–
,, *regularis* (Bruguière) d'Orbigny sp. ...	–	–	5	–	–	–
,, *pseudoregularis* Seitz	–	4	5	–	–	–
,, sp. nov.	–	–	5	–	–	–
leoniceras baylei (Jacob)	–	–	5	–	–	–
,, *subbaylei* Spath	–	–	5	–	–	–
,, cf. *leightonense* Spath	–	–	5	–	–	–
,, cf. *morgani* Spath	–	4	5	–	–	–
,, sp. nov. aff. *cleon* (d'Orbigny) ...	–	–	–	–	10	–
,, ? (gen. nov. ?) spp. nov.	–	4	5	–	–	–
onneratia parenti Jacob	–	–	–	–	10	–
,, sp. nov.	–	–	–	–	10	–
rotohoplites raulinianus (d'Orbigny)	–	–	–	–	10	–
,, sp.	–	–	–	–	10	–
oplites sp.	–	–	–	–	–	12
ypacanthoplites sp....	1	–	–	–	–	–
rotanisoceras raulinianum (d'Orbigny)	–	–	–	–	10	–
amites praegibbosus Spath	–	–	–	–	10	–

Fossils are exceedingly rare above Bed 10, but the occurrence of a ow-zonal type of *Hoplites* in Bed 12 permits a tentative correlation f this horizon with the 'greensand seam' near the base of the Gault t Folkestone, recently assigned to the Inaequinodum Subzone of the ammillatum Zone (Casey, R., 1950, p. 275).

In the bottom nodule-bed (Bed 5) fossils are scarce and are usually olled and fragmentary. They consist almost exclusively of ammonites, *Leymeriella intermedia* and *L. pseudoregularis* being the ominant species. The fossils are very irregularly distributed within the bed, and on one occasion several hours' search on this horizon was rewarded by the discovery of but a single fossiliferous nodule, about three cubic inches in volume, but which contained no less than fourteen small specimens of *Leymeriella*. It is probable that Bed 5 is the remanié *in situ* of several seams of phosphatic nodules, most of which were unproductive of fossils.

The assemblage of ammonites from Bed 5 and the sand immediately underlying it (Bed 4) indicates the Regularis Subzone, the topmost division of the Tardefurcata Zone, and is comparable with that described from the base of the Gault at Leighton Buzzard, Bedfordshire (Band I and part of the condensed Band II of C. W. and E. V. Wright, 1947). At Folkestone the same faunal horizon is found in the main mass of Price's second division of the Folkestone Beds (Casey, R., 1950, p. 270). The third area in England from which the Leymeriella fauna has been recorded lies between Lewes and Eastbourne, Sussex (*op. cit.*, p. 282).

A complete contrast in ammonite fauna is shown by the two principal fossil-bearing horizons (Beds 5 and 10) at Wrecclesham, not a single species being common to the two.

There is only one previous record of the uncoiled lytoceratid ammonite *Pictetia depressa* from this country. This was based on a specimen collected in 1915 by Lieut. C. S. Tinne from a temporary excavation at Wrecclesham and subsequently figured and described by Spath in his monograph of the Gault Ammonoidea (Spath, L. F., 1923, pp. 29–30, pl. i). It was attributed to the Mammillatum Zone, but the discovery of a second specimen at Wrecclesham *in situ* in the Tardefurcata Zone, and Jacob's citation (1907, p. 344) of *P. depressa* as a fossil of the Tardefurcata Zone, suggests that both specimens in fact had their origin in the latter zone.

Another noteworthy feature of the Wrecclesham Tardefurcata fauna is the presence of several species of ammonites belonging to an undescribed group which links the hoplitid genus *Cleoniceras* with the family Desmoceratidae. These ammonites are thus of interest in connection with current views on the evolution of the Hoplitidae: they may be compared with the forms of *Uhligella* recently described from the English Albian by the writer (Casey, R., 1949).

Investigations are now in progress in the Wrecclesham–Farnham area to provide information on the lateral extent of the Tardefurcata Zone. Specimens of *Leymeriella* and *Cleoniceras*, indicative of this zone, have been picked up in the small overgrown pit north of the road opposite Willey Mill, Farnham, mentioned by Dines as showing the base of the Gault (Dines, H. G., 1929, p. 41), but here the beds are largely obscured by overlying gravels.

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THE END-MORAINE NORTH OF FLAMBOROUGH HEAD

By A. FARRINGTON, B.E., D.Sc., and G. F. MITCHELL, M.Sc., M.A., F.T.C.D., M.R.I.A.

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CONTENTS

	PAGE
1. INTRODUCTION	100
2. NEWER DRIFT TOPOGRAPHY	102
3. OLDER DRIFT TOPOGRAPHY	104
4. CROMER RIDGE	105
5. CONCLUSIONS	105
REFERENCES	105
DISCUSSION	106

ABSTRACT.—The authors are of the opinion that the end-moraine which Lamplugh described at Flamborough Head is confined to the north of the head, and does not cross the head nor does an extension of the moraine appear in Holderness. They are of the opinion that the end-moraine north of Flamborough Head is relatively young in age, and is the equivalent of the Southern Irish End-Moraine in Ireland, and of the Jutland End-Moraine in Denmark. The authors have not seen any young morainic topography on the east coast of England south of Flamborough Head.

1. INTRODUCTION

IN 1891 Lamplugh presented to the Geological Society his famous paper 'On the Drifts of Flamborough Head' in which, among other glacial features, an end-moraine was described (Lamplugh, G. W., 1891). In the north of the area under consideration the western edge of the moraine blocked the mouth of the Vale of Pickering near Gristhorpe and Muston. From here the moraine was traced south through Hunmanby, up on to the edge of the Chalk escarpment near Reighton and then south-west through Speeton along the edge of the north cliff of Flamborough Head to Sanwick. This section of the moraine is described as 'a distinct chain' of 'kame-like ridges'.

At Beacon Hill on the south cliff of the head, about two miles due south of Sanwick, Lamplugh recorded 'a conspicuous mound-like feature' in whose section 'the arrangement of the beds . . . closely resembles that seen in many of the Holderness mounds, to which its likeness is indeed more striking than in the case of any of the mounds farther north'. In this mound at Beacon Hill, Lamplugh claimed to have recognised the same moraine and so the line of his moraine turned abruptly south at Sanwick, crossed the Flamborough promontory to Beacon Hill, ran out across a short section of Bridlington Bay, and then turned south-west into Holderness to follow a chain of 'kame-like mounds' through Barmston, Stonehills, Gransmoor, Kelk, Brigham, Frodingham and Brandesburton.

In 1929 Professor Charlesworth defined a line across England and Wales separating the 'Newer Drift' of northern Britain from the older drifts to the south (Charlesworth, J. K., 1929). The line began in the Cromer Ridge in East Anglia, ran along the eastern slope of the Lincolnshire Wolds, crossed the estuary of the Humber at Hessle and joined the moraine, as defined by Lamplugh, at Brandesburton. In 1928 Professor Charlesworth had defined a similar line in Ireland, 'the Southern Irish End-Moraine' (Charlesworth, J. K., 1928), and while the exact course of this line will no doubt be modified in detail by further work, it does represent the approximate southern limit of the last major ice-sheet of Ireland—that of the Midland General Glaciation (Farrington, A., 1949).

The drifts laid down by this ice have in general a fresh topography and are unweathered, in striking contrast to the older lowland drifts to the south of the line. On the Irish lowlands several of the very numerous enclosed basins on the fresh drift have been shown to contain stoneless clays, with scanty remains of *Salix herbacea*, laid down during the melting of the ice. The clays pass up into an organic mud with temperate plant remains, and this in turn is covered by a solifluction earth with *Salix herbacea* contemporaneous with the local ice-caps of the Athdown Mountain Glaciation (Farrington, A., 1949) on higher ground in Ireland. With the retreat of this last ice the post-glacial period began. Professor Jessen (1949), whose researches have revealed these late-glacial deposits on the Irish lowlands, is satisfied that the moraines and solifluction-earths of the Athdown Mountain Glaciation must be contemporaneous with the Fennoscandian End-Moraines and with the Ras in Norway, and that the organic mud must be contemporaneous with the Allerød period in Scandinavia. It is very probable that the Southern Irish End-Moraine of the Midland General Glaciation must be the equivalent of the 'main stationary line' in Jutland of the 'ultimate glaciation' of Denmark (Milthers, V., 1948). Dr. Milthers notes that this line divides an older levelled-out landscape to the west from the younger landscape of the ultimate glaciation to the east, and that along this line there is 'the most characteristic demarcation between the scenery of western and eastern Jutland'.

This last correlation has been already put forward by Dr. Movius who constructed a map (1942, fig. 8) uniting Charlesworth's line of end-moraine (modified in some details) across Ireland and Britain with the Jutland line. Movius recognised that if Lamplugh's line of end-moraine at Flamborough Head was correct, the ice, having once moved off the coast into Bridlington Bay, could only have been turned back into Holderness by ice already occupying the North Sea basin. Thus Movius was compelled to introduce into his map a great lobe of Scandinavian ice stretching far south into the North Sea even though considerable areas of Denmark were shown as ice-free at the same time.

2. NEWER DRIFT TOPOGRAPHY

In 1947 one of us (G.F.M.) visited the Vale of Pickering, and, as the morainic topography at Gristhorpe, Muston and Filey was found to resemble that of the Midland General Glaciation of Ireland to a very striking degree, it was decided to follow Lamplugh's line of moraine southwards. But as Flamborough Head was approached the strip of young morainic topography got ever narrower until it finally disappeared over the north cliff of the head. Most of the Flamborough promontory appeared to be very mature in topography and almost free from drift, while the topography of the drifts of Beacon Hill and of Holderness in general was found to be very different from that around Filey.

In 1949 the authors spent several days in the district mapping in outline the young topography north of Flamborough Head. Everywhere in this area the moraine retains the form it acquired when it was deposited by the ice, and it has not been seriously modified by subsequent denudation. There are many small steep-sided hills and steep-sided hollows (some of which may be true kettle-holes), and, where sections are available, they show unweathered material nowhere buried by a mantle of solifluction-earth.

The Bempton valley, which, as Lamplugh noted, runs south of and parallel with the cliff edge and the moraine, must have carried off much of the melt-water which, as it approached the south coast, cut a deep trench through the older drifts just west of the Danes' Dyke; this trench has been entered as a drainage channel on the map (Fig. 1). Just east of the village of Flamborough a shallow but well-defined channel cuts through the ridge which runs from the village out to the head. This also deepens into a steep-sided ravine as it approaches the south coast at the South Sea Landing. Immediately south of Hunmanby, Kendall and Wroot have described (1924, p. 786) the magnificent drainage channel (followed by the railway from Scarborough to Bridlington) which cuts through the Chalk escarpment at an altitude of 250 feet O.D. into a mature valley which leads on as a tributary into the Gypsey Race. Just south of the end of the channel a small mound of fresh gravel lies on the floor of the valley, and it is not impossible that the fresh gravels, noted by Lamplugh (1883) on the floor of the Gypsey Race, near Bridlington, may have come through this channel from the melting ice which lay to the north of the Chalk escarpment. If Lamplugh was correct in suggesting that the ice extended south of Flamborough Head, then an ice-dammed lake should have been held up in the valley of the Gypsey Race. In this instance a large flat-topped delta should lie where the water, which had passed through this drainage channel, entered the lake; instead we find only an indefinite gravel spread in the Bridlington area.

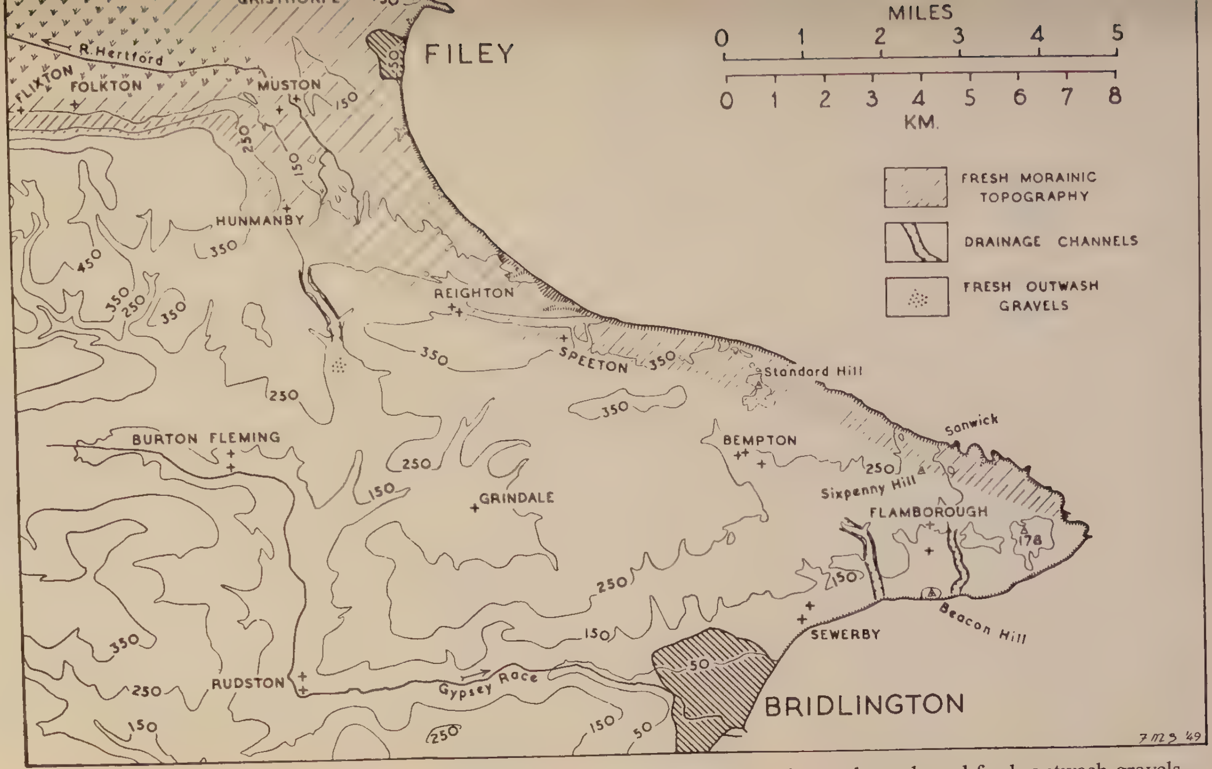

FIG. 1.—Map of Flamborough Head area showing morainic topography, drainage channels and fresh outwash gravels.

3. OLDER DRIFT TOPOGRAPHY

Beacon Hill and the mounds in Holderness at Kelk, North Frodingham and Brandesburton were also examined. Beacon Hill itself exhibits very smooth slopes fading into the surrounding lower ground with all the irregularities typical of young accumulation mounds quite smoothed away. The extensive sections to be seen in the gravel pits in the hill make it clear that this smoothing is largely due to denudation under severe climatic conditions which has brought a capping-deposit of solifluction-earth down onto the lower flanks of the hill. This capping deposit has been described by officers of the Geological Survey (Messrs. Dewey and Bromehead *in* Burchell, J. P. T., 1930) as follows:

> This top division attains a thickness of 9 feet on the eastern slope of Beacon Hill, and may average about 4½ feet along the rest of the cliff-section. It cannot therefore be regarded merely as 'soil', but in our opinion it is not a true Boulder-clay. Comparable deposits occur in the South of England, and have been described by the Survey Officers as 'Coombe deposits'. In our opinion this uppermost layer is of the nature of a 'Coombe deposit' or landwash formed under the conditions postulated by Clement Reid for the formation of Coombe rock.

The general aspect of the hill is quite different from the fresh morainic mounds near Filey or along the top of the cliff east of Speeton, and the authors can only consider the sketch of Carvill Lewis (1894, fig. 30) of the 'Moraine at Beacon Hill' as highly misleading.

Farther south the line of the moraine has been described as passing through a scattered line of mounds in Holderness, but apart from these low mounds of gravel, the terrain is quite featureless and the mounds themselves are very unimpressive if they are to be taken as the terminal moraine of a recent large ice-sheet. At Little Kelk a mound, roughly crescentic in outline and probably built up of gravel, is separated by a short gap from a low sinuous ridge which may be followed, with little interruption, past Great Kelk in general direction a little south of east for a distance of more than two miles. In a fine section at Great Kelk well-bedded clean gravel and sand with much shell debris reach up to the soil along the top of the ridge but, as one descends the sides, an ever-thickening mantle of down-moved material leads gently into the surrounding lower ground. The ridge is certainly not morainic. Both its sinuous form and the material of which it is composed suggest that it is an esker, though its gentle slopes and smooth contours preclude the possibility of comparing it in age with the eskers of the Midland General Glaciation in Ireland. It is not necessary to labour the point. The gravels at North Frodingham and, still more markedly, those at Brandesburton form broad spreads with smooth low slopes. Nowhere south of Flamborough Head as far as the Humber, nor even at Hessle itself, was any feature seen which, by its topography, would suggest correlation with the Midland General Glaciation.

To confirm earlier impressions the Norfolk coast sections from Happisburgh to Hunstanton were re-examined. It is usual to draw the edge of the Newer Drift parallel with the coast from Morston to Hunstanton. Charlesworth (1929) drew the edge as lying along the north side of the Cromer Ridge, but Movius (1942) followed the line defined by Dr. Solomon (1932) for the limit of the ice that deposited the Brown Boulder Clay at Morston and at Hunstanton. Solomon considers that this Brown Boulder Clay should be correlated with the Hessle Clay.

4. CROMER RIDGE

The Cromer Ridge, over the greater part of its extent, is mature, showing smooth and even slopes, and it is only at the northern edge that the topography is rough and uneven. Here, study of the surface indicates that the roughness is due to erosion and not to deposition. The north slope is trenched by deep valleys; here and there spurs run north towards the coast; sometimes mounds of gravel (as at Muckleburgh Hill) stand isolated from the main mass—nowhere can the 'tossed' topography of a young frontal moraine be seen. Valley-furrowed slopes ('false hills') are recognised as special erosion forms in Denmark (Milthers, V., 1948). It can at times be difficult to decide whether an isolated hill is a kame or a residual mound, but anyone familiar with the eskers of the Midland General Glaciation of Ireland will find an ascription of the Blakeney Ridge to a similar and contemporary formation difficult to accept.

5. CONCLUSIONS

The exposures of the Brown Boulder Clay at Holkham and at Hunstanton lie in a terrain of low relief, and the sections show a boulder clay which has been weathered to a considerable depth. The same features are to be seen at Hessle, and neither in Norfolk nor south Yorkshire does the relatively subdued topography or the weathered state of the drift suggest any affinity with the fresh features and materials of the drift of the Midland General Glaciation of Ireland or of the 'ultimate glaciation' of Denmark. As a result of their recent field work the authors are convinced that the moraine north of Flamborough Head is indeed a recent end-moraine which marks, on the east coast of England, the southern limit of the last major expansion of ice in north-west Europe, an expansion correspondingly marked by the Southern Irish End-Moraine in Ireland, and by the Jutland End-Moraine in Denmark. The authors could see no young morainic topography on the east coast of England anywhere between Flamborough Head and Happisburgh.

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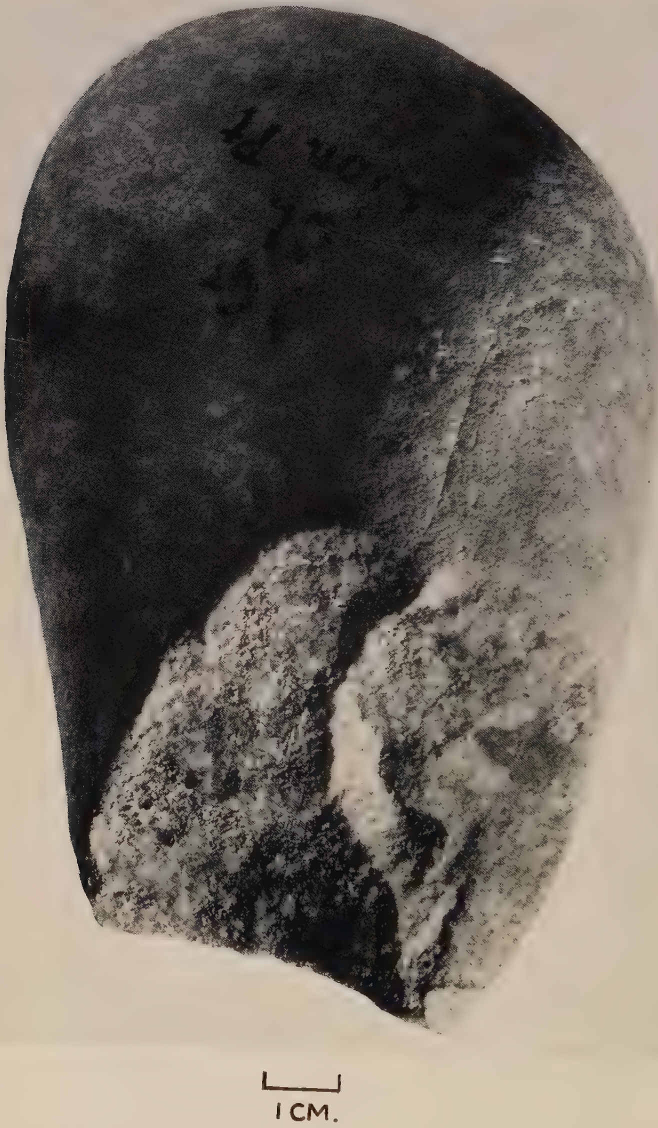
DISCUSSION

PROFESSOR HOLLINGWORTH particularly welcomed the authors' use of the morphology of the drifts as a basis of correlation. He had unfortunately only heard the latter part of the paper, but was particularly interested in the differentiation between the Flamborough Head topography and that associated with the Cromer moraine. Part of the latter had been considered as showing new drift topography by competent authorities and this appeared to fit in with the correlation of the Hunstanton Boulder Clay and with the Hessle Clay of the Yorkshire and Lincolnshire coastal belt. These two clays are said to have similar lithology and similar morphology. Did the authors accept this correlation and, if so, what was the relation of the clays to the Flamborough Head deposits? He would also draw attention to the significance of morphological studies of the drift to the monoglacial problem. According to Lamplugh's view of the matter it was possible to envisage a period of recession interrupted by oscillatory movements sufficiently prolonged to produce marked differentiation between the degree of dissection of the drifts, bared during the earlier stages, compared with those revealed or deposited during the later stages. Such differences appeared to be more difficult to account for if the growing tendency to interpret the disappearance of the ice-sheets in terms of stagnation and decay was accepted. It is also worthy of note that the authors' limit for the Flamborough drift fits in well with the distribution of fresh marginal drainage phenomena better than the old line which would extend the limit to the Norfolk coast. The authors were to be congratulated on a contribution to British Pleistocene studies which had important consequences.

DR. FARRINGTON, in reply, said that he thought that the Hunstanton and Hessle Boulder Clays might well be associated with the Cromer Moraine. The authors, however, would not go farther than saying that all three are older than the Newer Drift of Flamborough Head. If an equivalent of the Hunstanton and Hessle Boulder Clay is to be found at the northern side of Flamborough Head, or farther north, it would lie below the drift with fresh topography; although, of course, it may come to the surface in places where the new moraine is absent.



No. 12a. Pebble-tool in quartzite from Lion Point, Clacton.

Photograph by courtesy of the British Museum (Natural History).

To face p. 107.

THE CLACTON FLINT INDUSTRY: A NEW INTERPRETATION

By S. HAZZLEDINE WARREN, F.G.S.

(*Second Henry Stopes Memorial Lecture, delivered* 5 *May* 1950)

[*Received* 8 *June* 1950]

CONTENTS

PAGE
1. INTRODUCTION ... 108
2. FLAKING-ANGLE ... 108
3. FACETING ... 109
4. THE INTERPRETATION OF THE CLACTON INDUSTRY ... 109
5. THE RAW MATERIAL ... 110
6. PATINATION AND ABRASION ... 110
7. ABRADED (? DERIVATIVE) GROUP ... 110
8. BIFACE WORKING (NODULE-TOOLS) ... 111
    (a) Pointed nodule-tools ... 111
    (b) Choppers ... 114
    (c) Axe-edged tools ... 115
    (d) Discoidal forms and flake-discs ... 115
9. TRIMMED FLAKES, ETC. ... 115
10. FLAKES ... 120
    (a) Application of the flaking-angle ... 120
    (b) The bulb characters ... 124
    (c) The Clacton flake ... 124
11. CORES ... 125
12. ANVIL-STONES ... 126
13. EDGE-CHIPPING (NOTCHES, ETC.) ... 127
14. STRIATION ... 128
15. UTILISATION ... 128
16. WAS CLACTON MAN A USER OF FIRE? ... 128
17. BONE IMPLEMENTS ... 129
18. THE WOODEN SPEAR ... 129
19. THE CORRELATION OF THE CLACTON BED ... 130
20. OPINIONS ON THE CLACTON MOLLUSCA EXPRESSED BY THE LATE A. SANTER KENNARD ON 26 DECEMBER 1947 ... 131
21. CONCLUSION ... 132
22. APPENDIX—Analysis of the Clacton industry ... 133
ACKNOWLEDGMENTS ... 134
REFERENCES ... 134

SUMMARY.—The author interprets the Clacton industry as follows: nodule-tools which include choppers with segmental edge, pointed nodule-tools or proto-bouchers, axe-edged tools, discoidal and polyhedric forms which might be throwing-stones; also trimmed-flakes, knife-edged flake-blades, cores, and waste flakes.

The flint nodule-tools are made on the same plan (only somewhat more advanced) as the far earlier Pebble-tool industries of Asia and Africa. One pebble-tool in quartzite from Clacton might belong to one of those industries, but the trimmed flakes and flake-blades show greater advancement. Simple flakes of Clactonoid form are not, in themselves, evidence of a Clactonian industry.

It is suggested that the Clacton industry is of very early tradition—a modified survival of the early pebble-tool industries of Asia and Africa which spread into Western Europe as a major glaciation passed away.

1. INTRODUCTION

THE remains of big Mammalia from the Essex Coast deposits have attracted curiosity for many centuries. Camden's *Britannia* of 1610 quotes a record of a discovery that dates back to the twelfth or thirteenth century.

During the first half of the nineteenth century John Brown of Stanway, one of the early members of our Association, made important collections that were described by Owen. Further work was done by Boyd Dawkins, Osmond Fisher, and others too numerous to mention here as the present purpose relates to the flint industry. I believe that the credit of finding the first palaeolithic flakes in the Clacton Bed belongs to the Rev. J. W. Kenworthy, and his small collection is now in the Essex Museum of Natural History, but there is not enough to indicate the character of the industry.

I began collecting the Clacton implements about the year 1908. Professor Breuil published his monumental study of the industry in 1932, and further information was obtained from the scientific excavations of Dr. K. P. Oakley and Mrs. M. Leakey published in 1937.

The Clacton Bed is multiple and consists of the silting of several former channels of the Thames, the best exposures being on the foreshore and overlying cliff on the west side of Clacton itself, and the others on the foreshore at Lion Point (Jaywick). The former representing the silting of an almost stagnant backwater or abandoned loop of the river, while the other sites were freely flowing channels. There is now comparatively little opportunity for study owing to the effect of sea defence works, and it is many years since I saw the west Clacton site exposed (Warren, S. H., 1940, p. 8).

Before passing to the actual description of the industry there are certain points to be explained about the methods I have used.

2. FLAKING-ANGLE

When the beginner starts the flaking of flint his first discovery is that there is a rather low angle, say 58° to 65°, at which flaking can be done the most easily, but the first unskilful flakes are short and wedge-shaped, so that, as the work proceeds, the angle soon becomes too high and unmanageable. It needs greater skill to work successfully at the higher angles. Examination of Levallois work, for example, shows that these people struck their flake-implements at angles approaching, and occasionally above, 90°. But many good flake-blades are struck at 75° or even lower.

The conditions for making a keen cutting-edge by biface work are different, as it is then necessary to keep the flaking-angle low and to overcome the tendency for the angle to become higher with each flake struck or the edge becomes too blunt to be useful.

When I began measuring flake-angles the purpose I had in view vas to recover the solid angle on the core or biface from which the lake was struck, and at the same time to define the core—or biface—ngle, and the flake-angle on a common basis. To the original raftsman it was the management of the solid angle (high for some urposes, low for others) that was the main controlling factor in his vork. Speaking for myself it is the recovery of the solid angle from he flake that gives me an understanding of what the prehistoric raftsman appreciated by eye, hand, and flaking effect, and this I cannot btain in any other way. Other angles can be measured on flakes but hese do not give me the same information about the technique of rehistoric work. The application of the study of the flaking-angle vill be made clear under the heading 'Flakes' (p. 120).

3. FACETING

This aspect of the flaker's craft raises certain points that are nearly llied to the foregoing. In the earlier literature of prehistory it was stablished that the concavity left by the removal of a flake is a facet'. This has been largely replaced by 'flake-scar' which is unuitable except only in the case of cores. All uniface and biface implenents are shaped by facets, not by scars which imply some damage o the perfect form of any object.

I believe that the original purpose in limiting the use of 'facet' to he striking platform was to establish a simple criterion for the evallois industry, and it has been widely used in that sense. This is vrong, as the finishing flakes of biface implements, whether palaeothic or neolithic, often have similar faceted platforms. A return to he original, and correct, use of 'facet' would improve the description f implements, and avoid the mistakes of inferring Levallois indusries from the finishing flakes of bifaces of other dates (Warren, S. H., 919).

. THE INTERPRETATION OF THE CLACTON INDUSTRY

I have never been able to accept the view that the Clactonian was xclusively a flake industry, and that the pointed and chopper forms vere cores. In the past I have suggested that the pointed forms might e attempts by a more barbarous people to imitate the Acheulian oucher (as this was so well named by Sollas), but now a better xplanation emerges (Warren, S. H., 1932a).

During recent years the light that has been thrown upon the early ebble- and flake-tool industries of Africa and Asia has placed the lactonian in a new perspective (Movius, H. L., 1949; Oakley, . P., 1949). The correspondence between these industries and the lacton, apart from the pebble-tools becoming nodule-tools in int, is so close that one must conclude that Clacton is an offshoot f the tradition of these primitive industries. Oakley has reached a milar theory independently and this will be found in 'Man the

Tool-Maker' published late in 1949. The detailed evidences in favour of this will unfold themselves in the sequel.

There is a valuable summary, with references to the literature, of the African 'pebble-tool' and later industries published by the University of London Institute of Archaeology as 'Occasional Paper' No. 9 ('The Exhibition of Stone Age and Pleistocene Geology from the Cape to Britain').

5. THE RAW MATERIAL

A few of the implements are made from weathered flint, bearing the effects of long exposure on the surface. A small proportion of the material used was greatly abraded in a river bed (if not on a sea beach), and one or two are made out of Eocene pebbles, but the majority of the material selected for working was relatively fresh flint. Indeed, some might have been obtained direct from a chalk section: there is nothing improbable in this as some of the implements may have been made many days' walking distance away in any direction—primitive peoples are great wanderers. This would account for the apparent deficiency in the relative frequency of waste flakes. The peculiar 'marbled' flint that is familiar in the lower Thames Valley is common, while a few of the artifacts (such as No. 1) are in Bullhead flint.

6. PATINATION AND ABRASION

Many of the Lion Point artifacts are rather dull, fresh-looking, and unabraded; these must have been buried in the gravel quickly and remained undisturbed. Others have slight patination and abrasion, but only some three per cent are greatly altered. My late friend, Mr. A. S. Barnes, used to say that we ought to distinguish patination from coloration.

In coloration many of the Lion Point flints have a slight greenish tone, and the scarcer strong coloration is usually ochreous. I think these differences are mainly the result of being rolled in the river bed, or exposed to patinating agencies, before being permanently buried in the gravel.

The deposit at Clacton itself—the classical site—contains abundant plant remains, but no true peat. Here the artifacts have jet-black 'peat-staining'. The production of patinations is far from being fully understood, but M. E. Hue (*Bull. Soc. Préhist. France* 1929) obtained a deep intensity of black patination in twenty years by a one per cent solution of ammonium sulphide.

Unless otherwise stated the condition of all the artifacts illustrated come within this narrow range of variation.

7. ABRADED (?DERIVATIVE) GROUP

It is possible that some, if not all, of the three per cent of abraded artifacts may belong to an earlier phase of the industry, but I feel that one must await further comparative evidences from other sites before reaching a decided opinion. Heavy abrasion and patination can happen very quickly, and so far as time is concerned it would be perfectly possible for a man to pick up and re-work an abraded and patinated artifact that he had himself made some years before. In favour of derivation it is true that the abraded group are on the average heavier and clumsier than the unabraded but this might be the result of grading by water. Against the theory of derivation I feel that the occurrence of apparent derivatives among contemporary artifacts is too frequent, and suggests that the difference is accidental. Moreover the abrasion and patination makes them look more different than they really are. The flaking-angles of the abraded group, and also of the Swanscombe Clactonian, are a little higher than those of the main Clacton series, but, although this is the strongest apparent evidence in favour of derivation, I hesitate to be too confident of its validity. On testing the point I found that the larger unabraded flakes were struck at 3° or 4° higher angle than the small ones; so the slightly higher angle of the heavier abraded group might be the result of grading.

8. BIFACE WORKING (NODULE-TOOLS)

I think 'biface work' is usually a better term to describe flaking over both faces than 'core-implement', as core is a more appropriate definition of waste; 'core-implement' would serve well for utilised cores, or in some other special cases. Uniface means, of course, that the essential shaping of the implement is on one face only.

The pointed (proto-boucher) group comprises a systematic repetition of a well-defined type, and I am fully persuaded would never be questioned as a true biface if found in anything other than a Clacton association. Although primitive, it is admirable as a practical and serviceable tool to grasp in the hand and use effectively. As with the chopper and axe-edged varieties I cannot think that anyone who had the wit to do the flaking could be so stupid as to keep the flakes and throw the 'core' away.

(a) Pointed nodule-tools

Fig. 1 No. 1. This retains much of the cortex of the flint nodule. Some of the facets are truncated on both faces. Mint condition. Lion Point.

No. 2. A similar but rather thick and heavier example; bifacially unsymmetrical. Mint condition. Lion Point.

No. 3. A well-proportioned implement, thinner than most. Slightly abraded. Strong red patination of the present-day produced through lying in the path of a ferruginous spring on the foreshore. Lion Point.

No. 4. Smaller example, condition nearly mint, with black facets. Cortex and natural frost fracture on the reverse face are whitened from prolonged weathering on the surface. Lion Point.

No. 5. Very small, probably a child's size. Mint condition. Clacton Channel.

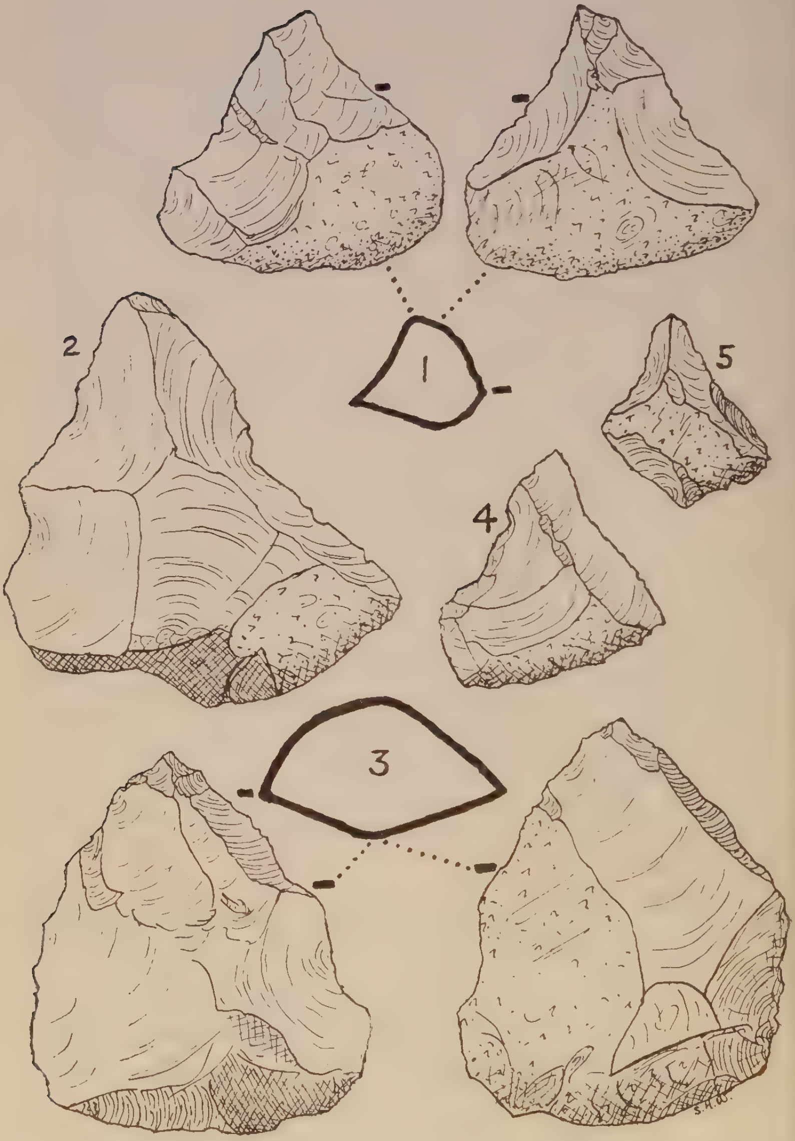


FIG. 1.—Nos. 1–5. Pointed nodule-tools from Clacton. (Half nat. size.)

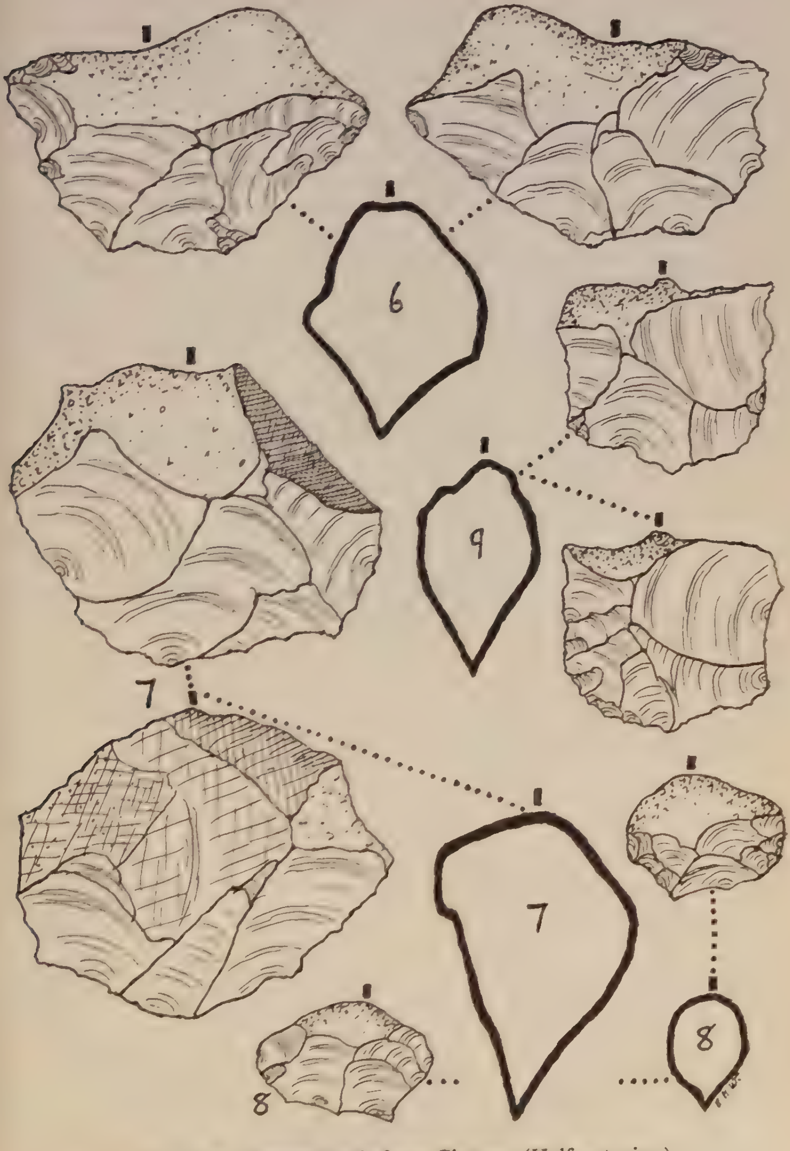


Fig. 2.—Nos. 6–9. Chopper tools from Clacton. (Half nat. size.)

(b) Choppers. Here also we have a systematic repetition of a well-defined type that is characterised by a zig-zag segmental edge; with a good hand-grip at the back. Few have more than five facets on either face, and the majority less; some have only three facets in all. It needs a certain measure of skill to attain the effective implement, true to type, with so little flaking. In plan these are identical with the chopper-tools of the early Asiatic industries. Three examples were illustrated by Worthington Smith from the Clacton III floors of Caddington and Stoke Newington; these he described as chopper implements without any question or doubt. (Smith, W. G., 1894, figs. 113 and 157–8.)

Fig. 2 Nos. 6 and 7. Two typical choppers, as defined above. Both from Lion Point.

No. 8. Very small, probably a child's size, but perfectly true to type. Lion Point.

No. 9. Rather small example, nearly mint in condition; the edge less zig-zag than most. Lion Point.

Fig. 3 No. 9a. Chopper of simple workmanship, both faces and the edge are shown in the drawing. This could not be a core, but is true to the chopper type, and well illustrates the tradition of the pebble-tools.

Fig. 4 No. 10. Proto-ovate implement? This is flaked all over both faces, and some of the facets are rather small. There are a few others somewhat similar but not enough to establish a type. One can only say that it is a biface edged-tool. This was found in the same situation as No. 3, but is only slightly affected by the red patination. Fig. 3, No. 9a, Fig. 4, No. 10. Lion Point.

No. 11. This is intermediate in form between the choppers and the axe-edged. The edge-angle is 60°–64°. Lion Point.

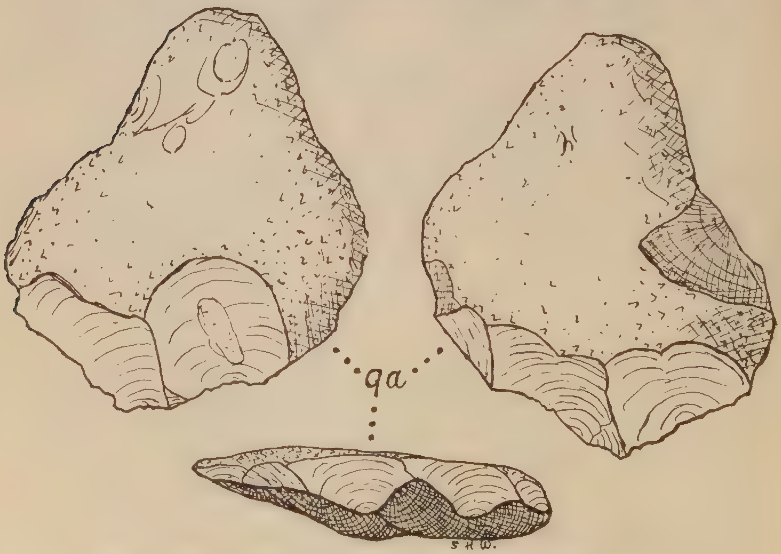


FIG. 3.—No. 9a. Chopper-tool from Clacton. (Half nat. size.)

(c) Axe-edged tools. This is another well-defined type, on the tradition of the early pebble-tool industries.

Fig. 4 No. 12. This is very characteristic of the type in the flint nodule-tools. Edge-angle 48°–67°. Lion Point.

Plate 4 No. 12a. Axe-edged pebble-tool in quartzite, with one facet on one face and two on the other. Edge-angle 87°. This might have come from any of the pebble-tool industries of Africa or Asia, and it supports the theory of the continuity of the early tradition. Two quartzite pebble-tools from Swanscombe are illustrated by Chandler (1930, figs. 17, 22). Lion Point.

(d) Discoidal forms and flake-discs. These are roughly shaped to an edge all round by flaking on both faces. There is no striking platform and no attempt is ever seen to obtain any useful flake in proportion to their size, as in the tortoise cores. They are abundant on some Neolithic sites, and many of these more recent examples are indistinguishable from Clacton work; in fact, the same is true of many choppers and axe-edged nodule-tools. Both the Clacton and the Neolithic groups pass into polyhedric forms with jagged points all round, which could not be cores, and I regard them as missiles for throwing. Some of the flake-discs may perhaps be sling-stones.

Fig. 5 No. 13. A rather small but typical example with remains of the cortex on both faces. Lion Point.

No. 14. A diminutive example, probably a child's size, also with cortex on both faces. Lion Point.

No. 15. Flake-disc made by flaking off the striking platform and bulb part of the flake. The secondary trimming which converts the flake into an edged disc is shown by heavier lines in the drawings at *S.S.* Lion Point.

No. 16. Another example of the same type of flake-disc. Clacton Channel.

No. 17. Diminutive polyhedric form or rough sphere with jagged points all round. Probably a child's size, but perfectly true to type. Lion Point.

9. TRIMMED FLAKES, ETC.

These are an important element in the Clacton industry, the remarkable bill-hook form, as I have named it, being the most distinctive.

(a) Side scrapers

Fig. 6 No. 18. Side-scraper with nearly straight edge, which shows considerable wear. This may be the result of original usage as there is little sign of abrasion elsewhere. There is a tendency to turn the corner on the left, a feature which was further developed in the High Lodge industry. This type is also characteristic of Clacton and there are most frequently three rather broad secondary facets. Flaking-angles, primary 56°, edge-trimming about 66°. Lion Point.

No. 19. Another example, flaking-angles, primary 51°, trimming 62°–68°. Lion Point.

No. 20. Small side-scraper, edge-trimming about 53°. Lion Point.

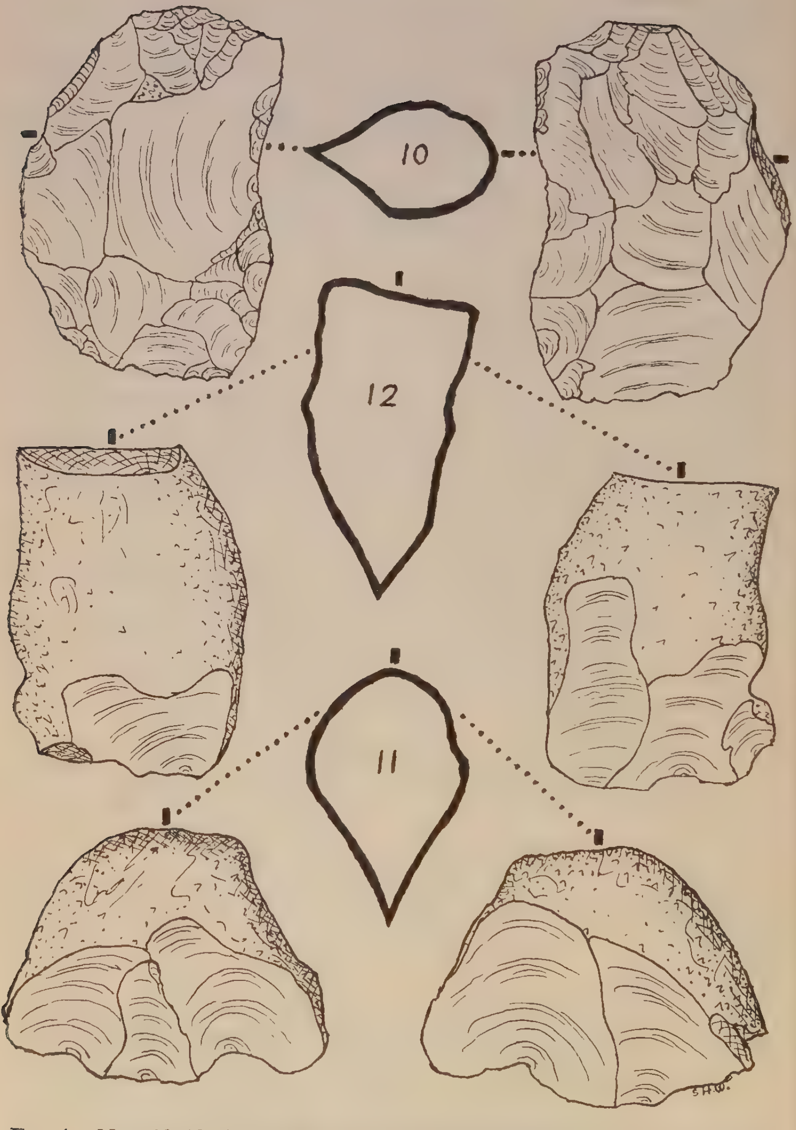


FIG. 4.—Nos. 10–12. Axe-edged and other tools from Clacton. (Half nat. size.)

(b) Bill-hook forms

Fig. 6 No. 21. Rather heavy example with a natural fracture on the flat side. Edge-angle in hollow about 54°, along outer curves 60°–67°. Lion Point.

No. 22. This is made in much weathered flint, of yellowish tone and rough texture. Flaking-angles, primary 63°, hollow edge 58°–74°, of outer curve 63°–80°. Lion Point.

No. 23. The best specimen of the bill-hook trimmed flake, carrying the most delicate secondary flaking yet found at Clacton. Flaking-angles, primary 63°, hollow edge about 53°, outward curve mainly about 80°, but some of the first flakes at 60°. Edge of outer curve much blunted by use. Lion Point.

No. 24. Another good example, turned the opposite hand to Nos. 21–23. The working edges of this are also much worn by use. Flaking-angles, primary 56°, hollow edge 64°–66°, outer curve 67°–90°. Clacton Channel.

(c) Various scrapers

Fig. 6 No. 25. Side-scraper of unusual type for Clacton, more abraded and patinated than most. Flaking-angles, primary 55°, edge trimming 61°–70°, but going up to 84°. Lion Point.

No. 26. End-scraper on blade with keen edge on left, the other being cortex. Flaking angles, primary 51°, edge angle 53°–60° with worn edge probably by use. Lion Point.

No. 27. Ellipti calscraper. Flaking-angles, primary about 64°, secondary about 65° or rather over, with a little up to 94°. Lion Point.

No. 28. Bulb-scraper, that is the secondary flaking removes the platform and part of the bulb on the inner face. Secondary angles 64°–88°. Lion Point.

(d) Sub-crescent forms. These are a well-defined but puzzling group. The core-crescent variety much resembles a well-known Egyptian type, but the technique is quite different and indicates that the purpose was not the same. They are not convincing to me as hollow scrapers, neither am I satisfied that they are cores. The flake-crescents are flakes with one deep and broad secondary facet struck out of one of the side edges; these pass insensibly into the bill-hooks in one variation, and into the flake-points in another. I feel that the core-crescents and the flake-crescents are nearly related one to the other; that they had some special purpose there can be no doubt, but I hesitate to suggest what this may have been[1].

Fig. 7 No. 29. Large core-crescent, drawn one-third scale. Angle of hollow edge about 64°. The flint is much cracked, a feature that is infrequent in the Clacton artifacts. Lion Point.

No. 30. Flake-crescent, or perhaps a crude bill-hook. The wide single-facet hollow (edge-angle about 54°) is indicated by a heavier outline. Slight trimming on the opposite edge. Primary flaking-angle 52°. Lion Point.

No. 31. Flake-crescent with wide single-facet hollow. Flaking-angles, primary 52°, hollow edge 56°. Lion Point.

No. 32. Flake-crescent? or flake-trimmed to oblique point. Secondary flaking-angles about 69°. Lion Point.

No. 33. Example of rudely trimmed flake, belonging to this general group, but difficult to classify. Secondary flaking-angle 56°. Lion Point.

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[1] Dr. K. P. Oakley tells me that he found an example of this type at Le Moustier. I also have it from Swanscombe.

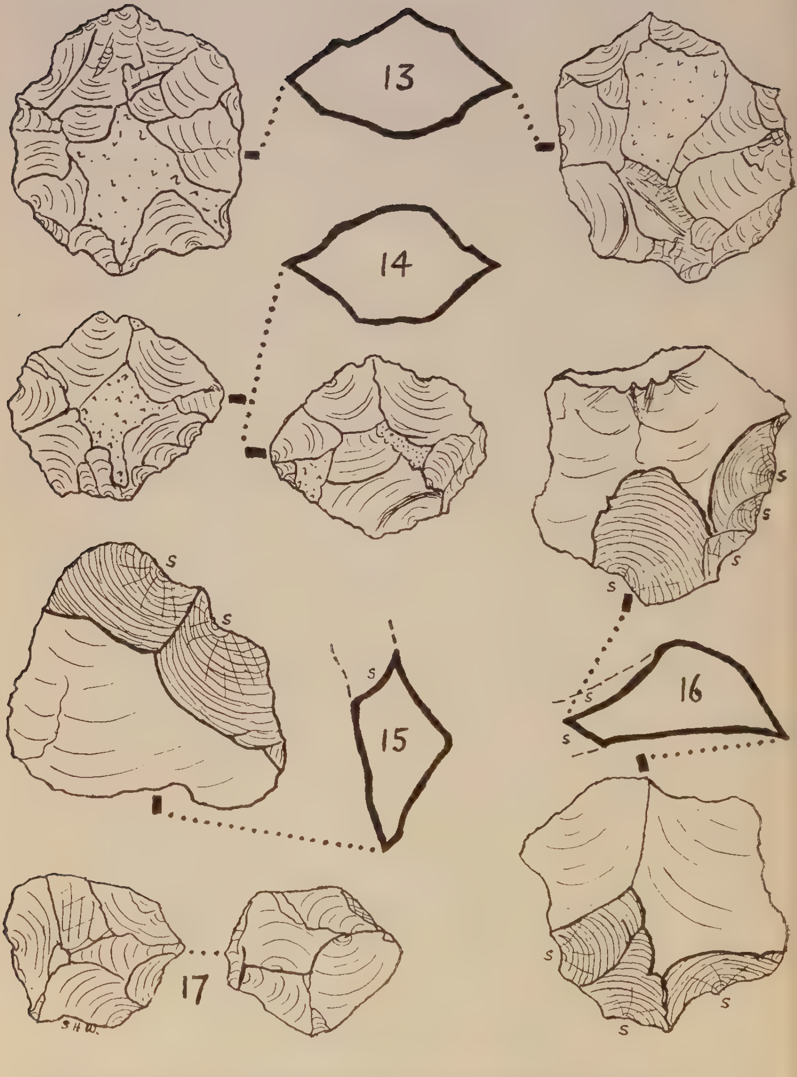


FIG. 5.—Nos. 13–17. Various discoidal forms from Clacton. (Half nat. size.)

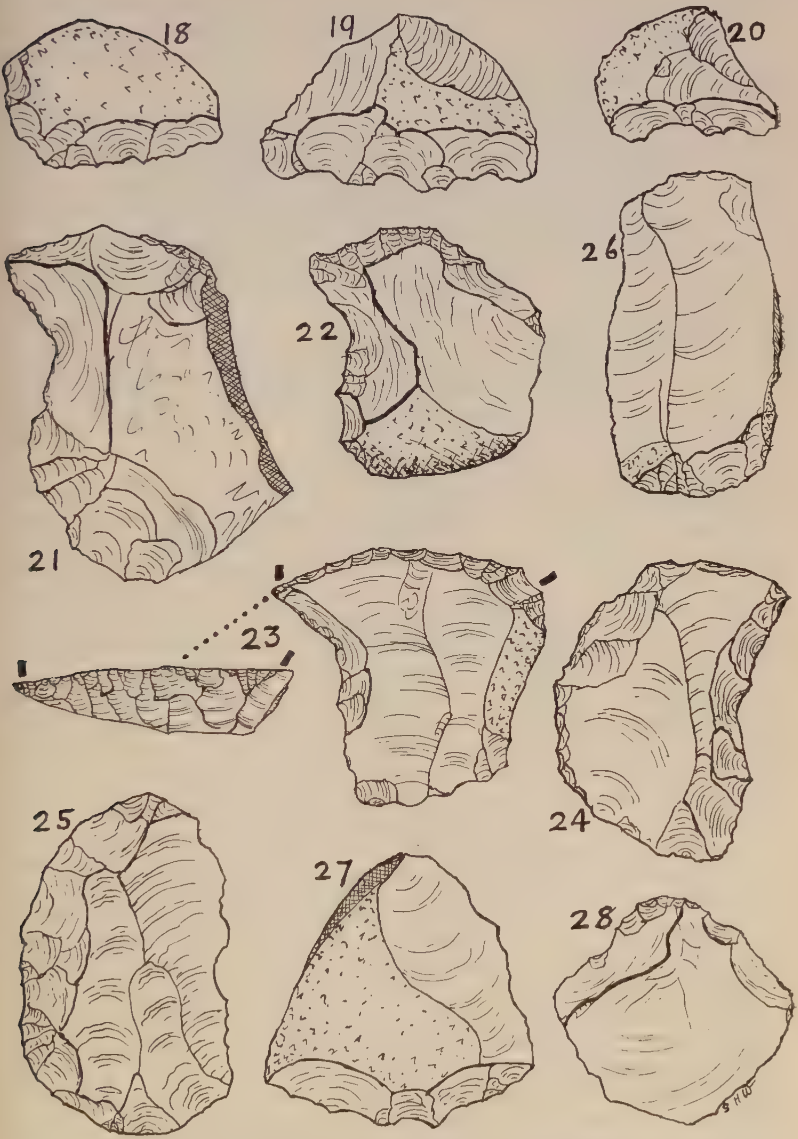


FIG. 6.—Nos. 18–28. Trimmed flake implements from Clacton. (Half nat. size.)

(e) Proto-Mousterian flake-points. There are a certain number of artifacts which might be interpreted in this manner, but these are neither so numerous nor so well-defined as the bill-hooks and flake-crescents: there is a strange dominance of oblique effects, straight points are relatively rare.

Fig. 7 No. 34. Primitive flake-point. Flaking-angles, primary 61°, secondary 57° on right, 84° on left. Lion Point.
No. 35. Flake rather neatly trimmed to oblique point. Flaking-angles, primary 70°, secondary trimming 57°–67°. Lion Point.
No. 36. Small flake-point, possibly a child's size. Flaking-angles, primary 55°, secondary 55°–60°. Lion Point.
No. 37. Another good example of the same group as the last, but made from an outside flake with weathered cortex. Flaking-angles, primary 54°, secondary 68° on right, 80° on left. Lion Point.

(f) Piercers

Fig. 7 No. 38. Represents a very persistent type uniformly made by a single facet on either side of the point: the superficial resemblance to No. 36 is accidental and not seen in the majority of this group. Secondary flaking-angles 62° on right, 58° on left.

10. FLAKES

(a) Application of the flaking-angle. Fig. 8, No. 39, and also the longitudinal sections of Nos. 40 and 43, will further explain my method of using the flaking-angle (see p. 108). Thirty-nine is a longitudinal section of a Clactonoid waste flake, *a b* is the broad striking platform with the bulb below *b*. The angle *a b d* is often taken as the flaking-angle, but it is just as easy to read the complement of this angle, namely *e b d*, and directly recover the solid angle, indicated by shading, on the core or implement and thus visualise the intention in the mind of the original craftsman. Whether on core or on implement, it is the solid angle *e b d* that was the operative angle of the work. It is only on a proportion of flakes that both the operative angle and the previous angle *b a c*, shown on the longitudinal sections of Nos. 40 and 43, can be measured on the same flake, as the surfaces are often too irregular. The angle *a b f*, indicated on the same two sections, called the angle platform-bulb, or *l'angle d'eclatement*, is also used by some.

The method of measuring the flaking-angle adopted here, also brings out the sequence of the flaking process, that is the difference between the previous (*b a c*) and operative (*e b d*) angles; this has some significance in understanding the technique. For example, I found that twenty unselected Clacton flakes, on which both angles could be measured, showed 7° average increase of the operative over the previous angle. Thus, if the flaker began at 61°, which is the average flake-angle, he would be at 82° after only three stages of flaking. Clacton man had not the skill to maintain a long sequence of flaking in any one direction. He was frequently compelled to start afresh in a new direction by cross-working the core. On twenty longitudinal finishing flakes at the axe-working site of Graig-lwyd, the two angles were, on the average, equal.

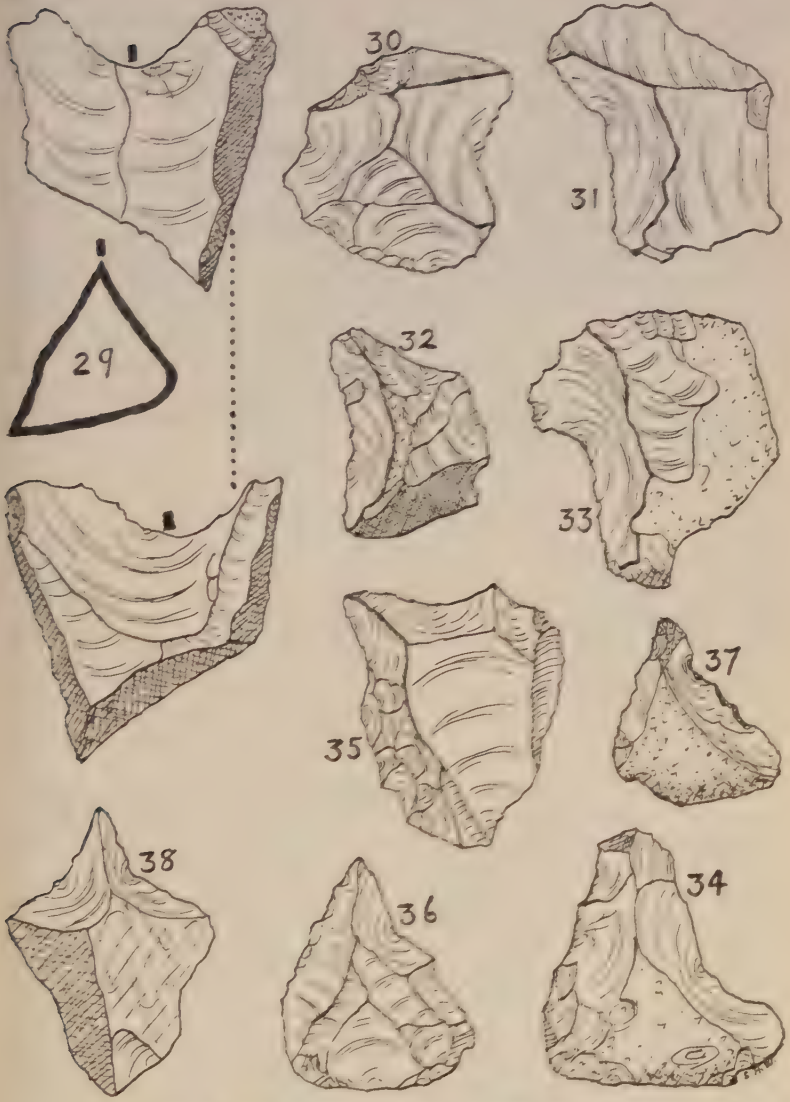


FIG. 7.—Nos. 29–38. Sub-crescent and flake-points from Clacton. (Half nat. size, except No. 29, which is one-third.)

In the Levallois industry a special technique was followed. The flakers worked at a very high average angle, 88°, and in order to check the tendency for this to become too high and unmanageable, they adopted the clever expedient of constantly re-setting the flaking-angle by faceting the platform after the striking of almost every flake-implement. When the right angle was obtained directly, the faceting was omitted.

In the measurement of the flaking-angles I take my original records to every degree, not in 5° groups as is sometimes done. I found that the method of plotting curves on squared paper resulted in an incomprehensible tangle of lines without introducing an unreasonable number of separate diagrams. After trying various methods of condensing and simplifying the results, I came to the conclusion that the middle line was the most important. From either side of this line I took 25 per cent, thus giving the range of the middle 50 per cent of the group. Beyond this again I similarly took 20 per cent each way, giving the main 90 per cent, thus leaving 5 per cent to either limit. Those extreme limits largely consist of splinters or failures to obtain the desired result.

The following table is a summary of the results:

Table 1.—FLAKE-ANGLES (in degrees)

		Limit	90%	50%	Mid	50%	90%	Limit
213	Clacton	37	47½	55	61	67	76	90
54	„ best	53	53½	62	65½	70	83	87
197	„ abraded	40	48	59	65	71	83	100
150	Swanscombe	46	49½	60	63½	68	80	100
208	Clacton III	46	53	63	69	75	84	95
45	Levallois	73	77	85	88	91	94	95
150	Acheulian (finishing flakes)	44	52	63	69½	74½	86	92
149	Mesolithic	56	62¼	71	77	83	92	101
115	Sub-Crag	60	66	81	96½	109	128	140

In every case the number of measurements is stated, as the extreme limits are of unequal value. The 213 Clacton are entirely unselected. The following fifty-four represent the best selected flake-blades. For the Swanscombe Clactonian from the lower gravel, I am partly indebted to the British Museum (Natural History) for a loan from the A. S. Kennard Collection, the remainder being my own. The 208 Clacton III are all from the Stoke Newington 'floor' (unselected material of my own). The Levallois are all flake-implements (excluding waste) from the Swanscombe pit, commonly called 'Baker's Hole': these are so uniform that even the small number gives a reliable indication of the industry. The 150 Late Acheulian flakes are from the Upper Dovercourt site and are largely composed of finishing flakes with faceted platforms struck by the bar technique in the making of the boucher. Faceted finishing flakes (both Palaeolithic and Neolithic) differ from Levallois flake-implements in the flaking-angle; moreover about half the finishing flakes carry no remains of

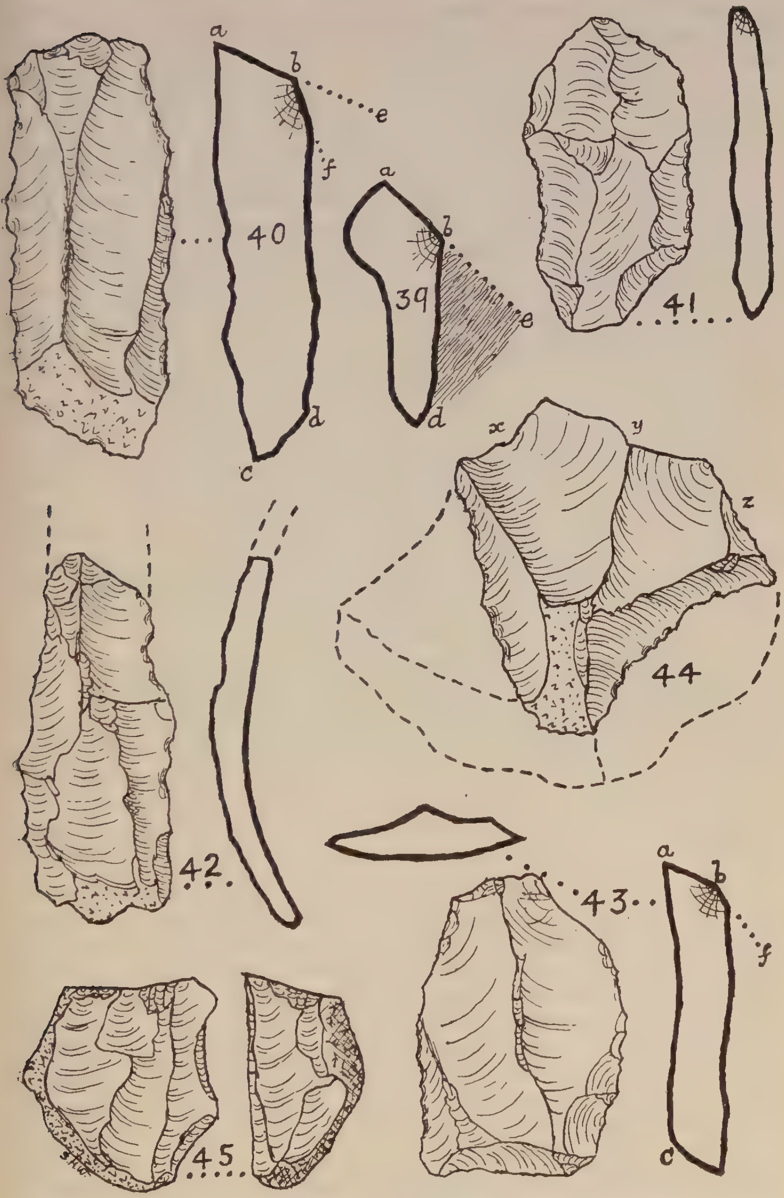


FIG. 8.—Nos. 39–45. Flakes from Clacton. The flaking-angle is also shown. (Half nat. size.)

the platform from which the flaking-angle can be measured and this is relatively infrequent in the Levallois, while the bulbs of the latter are more conical and do not accord with the bar-technique—the force was applied too far from the edge to be reached by the bar. The Mesolithic are all from the Broxbourne site, as in every case I have avoided adding to the number by mixing material from different sites. The 115 sub-Crag measurements are from material collected, over a very small area in a temporary excavation at Dovercourt, but representative of the flaking found generally below the Crags from this locality to Stoke-by-Clare and northward to the Cromer coast.

(b) The bulb characters. These are also an important item in the study of flakes. Strong conical bulbs are an outstanding feature of the Clacton flakes, but they are not so uniform as one might think from a general examination without making an exact count. I cannot find more than about 62 per cent of conical bulbs at either Clacton or Swanscombe, and about 19 per cent in the Clacton III group. Both the Clacton and Swanscombe groups contain about 10 per cent of nearly flat bulbs, against nearly 40 per cent with Clacton III (and 70 or 80 per cent with pressure flaking). The *éraillure*, or small splinter across the bulb, is present to about 65 per cent in all three groups; I have many records of the absence, or presence to varying degrees, of this feature but cannot find that it adds materially to the information. In reviewing its mode of occurrence I cannot at present see that it points to any particular conclusion.

The angle platform-bulb, *a b f*, is closely related to the angle of the core itself and I do not think that its significance is fully understood. My general impression is that it depends a good deal on the position on which the blow falls, and perhaps also on the velocity of the impact. The conditions are complex and I have not made an adequate study of this point, but it seems to me that where the blow falls far back on the platform the cone angle is wider than where it falls near the edge.

(c) The Clacton flake. One can summarise the special characteristics of the Clacton flake as having a broad platform, strong conical bulb, and low flaking-angle. But I do not think that half the Clacton flakes would conform to all these characters at once. Neither are the differences, when fairly assembled and analysed, so great as they appear to the eye. Although the Clacton industry includes good flake-blades and trimmed flake-implements, my personal opinion is that the conventional Clactonoid flake is the waste, and not the purpose, of the industry; and further that it is not, by itself, a safe indication of the Clactonian.

The analysis of the industry shows that there are only a proportion of about two and a quarter flakes to each of the core and biface group. This means a marked deficiency in the number of flakes recovered; perhaps some of the implements were made elsewhere, possibly at a section in the Chalk, but it must not be forgotten that the Clacton site is not the actual living floor, but the river bed, and it may be that grading by water transport carried many of the smaller and lighter things further away.

With reference to the technique of the trimmed flakes, much of the re-touch is very simple and consists of single facets struck by free, bold, flaking at low angles; but there is also a good deal of trimming executed in two or three stages at progressively higher angles.

Fig. 8 No. 39. Section of spall or waste flake. Flaking-angle 49°. (For further description of this, and also of Nos. 40 and 43, see under ' Application of the flaking-angle ', p. 120.) Lion Point.

No. 40. Two-edged flake-blade of ridged form. Strong conical bulb. Somewhat abraded and much scratched on the inner face only. Both the previous and the operative angles are about the same, namely 64°. Lion Point.

No. 41. Thin two-edged flake-blade. The ripples indicate that the facets on the outer face were struck from different directions; a frequent feature at Clacton. No cortex remains. Flakes such as this, of an emphatically non-Clactonoid form, are in a minority, but not extremely rare. The bulb is not strong. The flaking-angle may have been about 80°, but there is not enough of the platform to make a reliable measurement possible. Lion Point.

No. 42. Thin two-edged flake-blade, strongly incurved; bulb end broken off. A fine piece of work with parallel facets on the outer face, exceptional for Clacton. Lion Point.

No. 43. Two-edged flake-blade, broad and rather thin. Both flaking-angles about 62½°. Lion Point.

No. 44. Chopper dressing spall. The platform is replaced by the truncated facets at *x*, *y* and *z*, from the reverse face of the chopper. The last-named feature distinguishes this group of spalls which is prominent at Clacton. The possible outline of the chopper from which it was struck is suggested by broken lines. Both flaking-angles about 56°, but the surfaces are rather curved and irregular. There are also a number of corner spalls. Lion Point.

11. CORES

Fig. 8 No. 45. Small but typical core, the side not shown in the face view being entirely cortex. Lion Point.

There are many flint nodules from which only one or two flakes have been struck; I call these trial pieces, as many were obviously discarded on account of poor flaking quality of the material. The good cores usually have a flattish working face, many of these carry three parallel facets, but the work is seldom exact. I have nothing from Clacton that approaches regular prismatic or conical working, for, as previously noted (p. 120), they seldom continued parallel flaking for long, but frequently re-started in a fresh direction, thus cross-working the core. The platform is frequently formed by a single lateral facet.

The flaking-angle on the cores represents the final stage at which work was stopped, but the highest angles are not true flaking but splinters that flew off wrongly where the intended flake failed. The core angles are summarised on the same method previously described for the flakes, and are as follows:

TABLE 2.—ANGLES OF CORES AND BIFACE WORK (in degrees)

	Limit	90%	50%	Mid	50%	90%	Limit
223 Clacton	46	59	67½	72½	78½	90	113
42 „ abraded	61	62	68	72½	80½	94	102
86 Swanscombe	55	64	72	79	85	98	119
157 Choppers	40	53	59	64½	71¼	83	90
87 Axe-edged	42	52	55	60¾	66	74	80
104 Mesolithic	45	54	64¼	73½	79	87	97

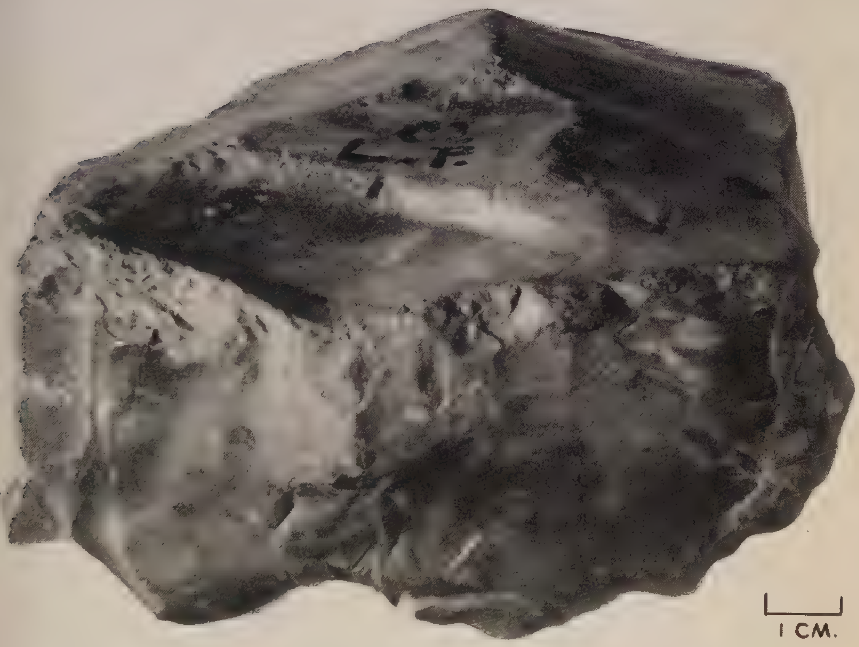
The first three groups of Table 2 correspond with those of the flakes previously described (Table 1, p. 122). In the case of the choppers and axe-edged, the measurements are of the working edge only, and I think the lowness of these angles supports other lines of evidence in favour of these being true implements and not cores. For comparison I found the average edge-angle of my best preserved Neolithic axes to be 61½°. But there is a considerable margin of variation (I have 47°–75°) and it would be incorrect to say that a cutting edge must be lower than any particular angle. The concavity of the facets results in a kind of 'hollow-ground' effect on the edges of all implements made by biface flaking; but the edges of many polished implements are surprisingly high-angled, often over 80°.

The Mesolithic cores are from the same site as the flakes, and it will be noted that in place of being 10° to 15° higher the cores are actually somewhat lower than the flakes. This is evidently because a large number of the flakes carry no trace of the platform so it is not possible to measure the angle. Scarcely 30 per cent of the larger flakes, and very few of the smaller, can be measured, and this must surely be the explanation of the deficiency in lower-angle flakes. The same condition is found in many other industries. In these cases the flake-angles are seriously misleading unless checked against the core angles defined upon the same basis.

Edge-struck flakes, many of which carry no platform from which the flaking-angle can be measured, are often made by the bar-technique, but I would not claim that this is necessarily the case in all circumstances. A near-equivalent is obtained by using a pebble hammer-stone with a rigid wrist—thus, in effect, converting the fore-arm into a bar.

12. ANVIL-STONES

I have found no well-defined hammer-stones, such as occur in abundance on many prehistoric sites, during my collecting at Clacton. Many rather large flints carry a localised battering along a conveniently placed edge, that I think can best be interpreted as anvil-stones. None of them is heavier than six pounds, and they could only be used for the smaller flaking. A heavy block of sarsen or other



No. 46. Anvil-stone from Clacton.

Photograph by courtesy of the British Museum (Natural History).

[*To face p.* 126.

boulder would be needed for the bigger flakes. One of these anvil-stones is illustrated in Plate 5, No. 46.

It is noteworthy that, whereas other experimenters have found that anvil-flaking produces strong conical bulbs, I found that anvil-flaking, which I then called 'reverse flaking', gave less than 10 per cent of well-developed bulbs, the majority being nearly flat fractures (Warren, S. H., 1914, p. 445). I think the explanation lies in the complexity of the conditions that influence the result, such as (a) the position of the point of impact—how far from or near to the edge; (b) the elasticity both of the anvil-stone and of the support on which it is placed; (c) the force, and the velocity, of the blow; (d) the quality and the condition of the flint; (e) the elusive factor of the skill of the operator—like the skill in games where one performer can do what another cannot.

In the bar-hammer technique the blow falls on the edge, and cannot reach the position far back on the platform that is usual with the Clacton technique. The latter method exerts a force of compression resulting in the cone, whereas the bar-technique pulls the flake away and the bulb lacks the sharp compression-cone.

I will not attempt to explain fully the technique of Clacton flaking, but my impression is that it involves very free blows, delivered at a high velocity with great muscular power. I agree with the general opinion that the anvil (or 'block-on-block') method was used for the smaller flaking, and, perhaps, for larger flaking, but I do not rule out the possible use of the hammer-stone as well. Oakley records one pebble from Clacton (Oakley, K. P., and Leakey, M., 1937, p. 237), and Chandler illustrates two pebble-tools in quartzite from Swanscombe which are battered at the butt as if from use as hammer-stones (Chandler, R. H., 1930, figs. 17, 22). Moreover, speaking from my own experiences, I find the following the easiest and surest way of obtaining reproductions of the Clactonoid flake: I start by selecting a low solid angle (as was the general habit of Clacton man), use a quartzite pebble that is relatively light for the intended size of flake, deliver the blow far back from the edge, and at the highest velocity I can attain.

Both anvil- and hammer-stones are recorded from the Clacton III industries (Smith, W. G., 1894).[1]

13. EDGE-CHIPPING (NOTCHES, ETC.)

Many of the Clacton flakes carry high-angle edge-chipping of the familiar 'eolithic' type, in which notches, either single or in various combinations, are a prominent feature. Much of this edge-chipping is later than the patination of the flint, and it is not infrequently associated with striation. I regard all this as being the effect of mechanical movement-under-pressure.

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[1] Since the above was written a note has appeared in the 1949 volume of the *Proceedings of the Prehistoric Society* on 'Experimental Clactonian technique' by D. F. W. Baden-Powell. The author has found, as I have done, that the easiest method of reproducing Clactonoid flakes is with a hammer-stone rather than by the anvil technique.

This special association of effects is frequent among prehistoric implements, Neolithic no less than Palaeolithic. It was noted by T. T. Paterson (1937) among the Clactonian of Barnham, although it was attributed by him (I think mistakenly) to human agency.

There are, however, at Clacton, a few examples of notches and double-notches which may be genuine human artifacts, although it is difficult to be sure. These are formed by facets that are more concave than is usual with mechanical pressure, and they appear to have been struck by separately directed blows instead of being crushed out against a resistant surface.

14. STRIATION

Striation of flint surfaces may arise from many causes. This does not necessarily point to solifluxion conditions characteristic of a cold climate, to say nothing of land-ice. It can arise from ordinary soil-creep during any climate, or from other causes such as the feet of men or animals; I assume also that it could be due to the growth of tree-roots.

I have found scratches on gun-flints, and obtained them experimentally with sand under as low a pressure as fourteen pounds.

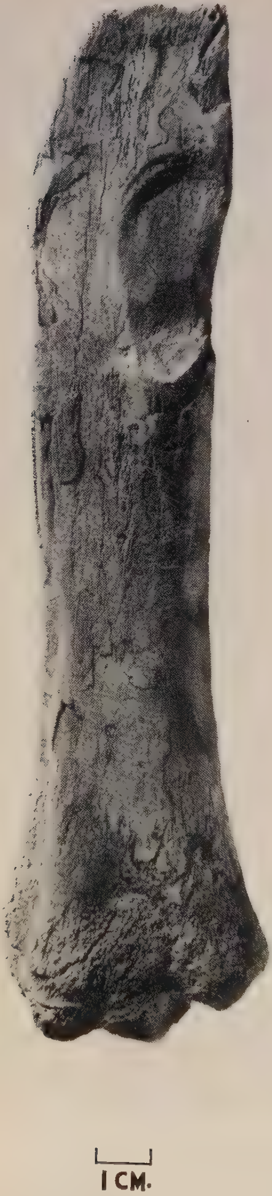
Striation is frequent at Clacton, and both there and at Swanscombe there is often a notable difference in the amount of the scratching on the two faces of the same flint. Sometimes, as in No. 40, it is confined to one face. On the latter specimen abrasion, as well as striation, is confined to the one (inner) face. The explanation I would suggest is that it was half embedded in the ground, and that the scratches, and also some casual chippings of the edges, were caused by the feet of animals.

15. UTILISATION

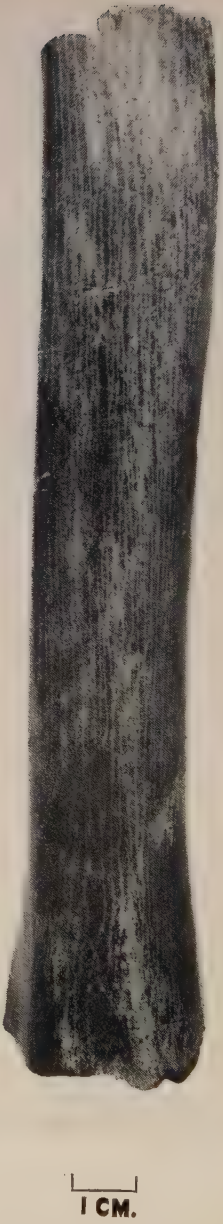
A certain number of prehistoric artifacts carry unmistakable signs of blunting by use, like Nos. 23, 24 and 26, but this is usually localised to some particular part of the implement. Where flakes are preserved in mint condition one seldom sees the scattered, casual, chipping of the edges that is sometimes thought to be utilisation. Undoubted evidence of blunting by use is not so frequent as one might expect. Flakes are made so quickly and easily that they would generally be discarded equally freely, before they had become obviously blunt.

16. WAS CLACTON MAN A USER OF FIRE?

In all the immense amount of Clacton material that I have collected I can find no trace of the effects of fire on the flints, neither have I seen it at Swanscombe. Dr. Oakley tells me that his experiences agree with this. In the High Lodge industry (or Clacton III)



No. 47 (left). Bar-hammer in bone. Jaywick excavations.



No. 48 (right). Bone polished by use at upper end. Clacton.

Photographs by courtesy of the British Museum (Natural History).

To face p. 129.]

of Stoke Newington rather more than 1 per cent of the artifacts are slightly burnt, but here there is strong Acheulian influence which is absent at Clacton.

One cannot venture to answer the above question definitely and can only state that no evidence of fire has been found.

17. BONE IMPLEMENTS

There are a certain number of splintered bones which may be associated with human activities but these for the most part do not suggest any recognisable purpose and so must remain very uncertain. Others show cuts such as might be made by flint artifacts in removing the flesh for food. One cannot be sure; and in any event such things are of little value.

There are, however, a few definite bone implements about which there can be no doubt.

Plate 6 No. 47 is a bar-hammer battered at either side, a short distance from the upper end as shown in the photograph. There are also flakes splintered off the surface from either side. The bone is the tibia of deer. There is another similar (not illustrated), which is only battered and flaked on one side. Jaywick excavations.

No. 48 has a polished surface at the upper end, and shows the results of prolonged wear by rubbing; it may be described as a burnisher. The bone is the radius of deer. There is another similar, much more highly polished and worn down, but badly broken up. The latter had been thrown out of the drainage trenches when Butlin's Holiday Camp was being made, but I was unable to recover all the pieces. Clacton.

Plate 7 No. 49 illustrates a probable axe-edged chopping-tool made out of the radius of a rhinoceros. I am indebted to [the late] Miss D. M. A. Bate for the determinations of the above fragmentary bones. None of these bone tools has previously been illustrated but this specimen was recognised as an undoubted implement by Professor Breuil many years ago. Clacton Channel.

18. THE WOODEN SPEAR

This broken point of a wooden spear, fifteen and a quarter inches long and one and a half inches in diameter, has been described and figured many times (Warren, S. H., 1911; Crawford, O. G. S., 1912; Oakley, K. P., 1949). Its surface shows a few cuts probably made by sharp flint flakes, but as a whole it is remarkably well smoothed off and finished. This discovery remained unique for nearly forty years, and it was a great satisfaction to me to learn that a much more perfect spear had been found between the ribs of an *Elephas antiquus* by Dr. Jacob-Friesen in North Germany (Jacob-Friesen, K. H., 1949, b.). I am indebted to Dr. C. R. Metcalf for identifying the wood of the Clacton spear at Kew. It is interesting that both the Clacton and the German spears are made in the wood of the yew. I understand that a flint industry has been found in association with the German spear, but this is not yet published, and it should not be assumed that this is Clactonian.

19. THE CORRELATION OF THE CLACTON BED

This paper is concerned with the flint industry, and I do not propose to go beyond a brief outline of my approach to this difficult problem. It seems to me that we are apt to overlook the implications of the fact that rivers have three main contemporary levels, namely: (1) the river-bed covered by the normal depth of water; (2) the ordinary flood-plain; (3) the occasional high-flood level.

Lyell (1845, p. 103) records the complete filling of a canal, during a single flood, with coarse gravel containing large stones, at twenty feet above the Delaware River. A rise of twenty feet is far from the limit. At the present day, continental rivers sometimes rise vertically to fifty feet, or even more, above their normal water level, and to that must be added the ordinary depth of water to the river-bed. Having regard to the torrential character of our Pleistocene river gravels we must allow a substantial vertical range for contemporary deposits, further increased by the effects of submergence and emergence of the land, and possibly complicated by some warping of the crust. Conversely, it follows from this that there will be deposits of different dates at the same level.

I do not think that enough consideration has been given to the elucidation of these complexities, and I will not attempt to straighten it all out, but I am convinced that some of the deposits on the 50-foot terrace are older than some of those on the 100-foot. There is something to be said for a wider use of an intermediate term, such as Iver Terrace—in fact, some years ago I did suggest a middle term, 'The Furz Platt Stage', to include the Middle Gravel of Swanscombe, the basement or river-bed gravel of the 50-foot terrace of North London, with Grays and Clacton closely associated in date. On the whole I now think it better to use a rather vague general grouping according to level and position, with the understood qualification that this includes an overlap in detailed dating.

In date, I agree with Oakley that Clacton probably comes somewhere between the lower and middle gravels of Swanscombe, but it is also closely related to the older brickearth of Grays which is physically part of the 50-foot terrace—in fact, it goes down to about the O.D. level.

But to return to the Essex coastal evidence which is nearer to the limited purpose of this paper. On the Tendring plateau, which may be said to overlook the Clacton channel at seventy or eighty feet above it, we find an outstanding illustration of deposits of different dates at the same level (Warren, S. H., 1940, p. 9). Although this plateau is dissected by numerous later valleys, it still remains essentially the plain of marine erosion of the Crag sea. It is traversed by numerous channel deposits of different dates, all at the same level, the oldest belonging to the Cromerian. The most puzzling of these is a gravel at Upper Dovercourt, on the edge of the plateau immediately above the

Stour valley. Now the Stour is pre-glacial, and where Wrabness forms a partial obstruction jutting out into the valley, the London Clay and overlying gravel are thrown into violent contortions down to sea level. Yet the flint industry of Upper Dovercourt, if I am not mistaken in dating it, is very near to the final Acheulian; in any case, certainly later than Clacton. How did this channel deposit come to be in such a situation? The site occupies a well-marked hollow, and the explanation I would suggest is that it represents a storm-gully where flood-waters plunged over the edge of the plateau into the Stour valley. This implement-rich deposit is very local, and no trace of it has appeared in numerous adjoining excavations that I have seen.

The extensive sheet of gravel at, and to the east of, Clacton, known as the Holland gravel, lies below the level of the plateau, at about 40 to 45 feet O.D., and above the Clacton Bed. John Brown stated that the Clacton channel was cut through this sheet, but I have never seen the junction. Oakley (Oakley, K. P., and Leakey, M., 1937, p. 258) showed that it was not a Thames gravel, but that its constituents are of local origin. That is at present all that is known about it; I have searched much and found neither artifacts nor bones.

Some of the patches of gravel on the plateau at Frinton, and other places further inland, yield Lower Palaeolithic implements, apparently Abbevillian; other patches, Clactonian forms; but many have yielded nothing. Some gravel near Wivenhoe appeared to be glacial, judging by its igneous erratics. At Ardleigh there is pre-glacial pebble gravel.

I am indebted to Mr. F. H. Edmunds and in part also to the late Mr. A. S. Kennard for the information that four borings put down by the War Office in 1944 at East Wick, near Burnham, struck a deep channel, going down to – 125 ft. O.D., filled with estuarine deposits with *Corbicula fluminalis*. As estuarine beds with this shell also overlie the Clacton Bed, there would appear to be a possible association between them.

20. OPINIONS ON THE CLACTON MOLLUSCA EXPRESSED BY THE LATE A. SANTER KENNARD ON 26 DECEMBER 1947

The Mollusca from the excavations at Butlin's Holiday Camp during 1938–40 are the same as those from the lower foreshore deposits at the West Clacton site: this is the earliest stage of the Clacton sequence.

During the final stages of the recent war a rocket struck the concrete sea wall near the centre of the Clacton channel and threw up a mass of shelly sand from below the parade which had not been seen for many years. I made a large collection from this in 1945, which I called the 'rocket site', and Kennard found that this was the same shell-bed from which the early collections were made. It included *Vertigo pusilla* Müller recorded by S. V. Wood but of which no extant examples were known. He identified these Mollusca with those of both the Lower Gravel and the Lower Loam of Swanscombe, species of *Lymnaea* and *Valvata* in particular being identical. The Corbicula Bed in the upper part of the Clacton cliff, and also the shell-bed at Lion Point that lies between the underlying gravel and the estuarine beds, he grouped with the 'shell-pit' of Ingres Vale.

It should be stated that the corbiculas mentioned above are drifted shells in the estuarine beds, and the latter can hardly be earlier than the estuarine beds on the foreshore at Lion Point.

I might take this opportunity of correcting a minor error in Kennard's description of the Lion Point shells (Warren, S. H., 1932b, p. 29). He states that the valves of the unios are always separate. This is incorrect as there were immense numbers with valves united.

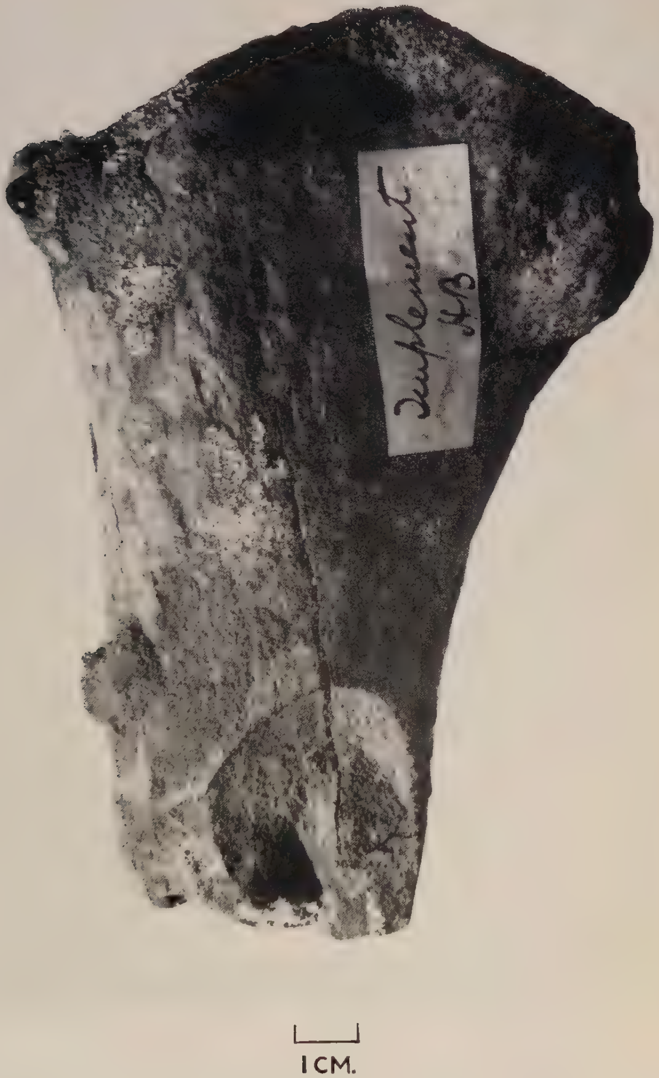
21. CONCLUSION

In summarising this interpretation of the Clacton industry I would stress the point that while keen-edged flake-blades and trimmed flake implements form an important section of the work, in my view the conventional Clactonian spall is the waste and not the purpose of the industry. My primary definition of the industry rests on the nodule-tools, particularly the chopper, pointed and axe-edged. In the past these have been widely classed as cores, but now that the early pebble-tool industries of Asia and Africa are accepted I feel that the two groups are so similar the one to the other that the primitive Clacton bifaces must be placed on the same footing.

Accurate analysis of unselected Clacton material shows that the conventional idea of a Clactonian flake is less diagnostic of the industry than might appear from a general impression. Moreover, flakes, which one might describe as Clactonoid, may result during the preliminary blocking-out in other industries of any date and should not be called Clactonian in the absence of more reliable associates.

With regard to the origin of the Clacton tradition I would point to the vast distribution of the early pebble-tool industries from Africa to East Asia, and suggest that surviving communities in this early culture might well penetrate into Western Europe when the climate was favourable during an interglacial stage. These people would naturally apply the ancient tradition of the pebble-tools to the flint nodules of our country. I think it would be justifiable to define these early pebble-tool industries as Proto-Clactonian.

Professor Movius has noted the 'Clacton-like' flakes associated



No. 49. Axe-edged implement in bone (Pebble-tool form). Clacton Channel.

Photograph by courtesy of the British Museum (Natural History).

[*To face p.* 132.

with the pebble-tools, and while I should not consider this adequate evidence to suggest any definite affinity, I think it has contributary value in support of the more important comparison with the flint nodule-tools.

To turn for a moment to the later history of the Clactonian tradition, one may recall that, in the first paper of 1922 on the Clacton industry (then called Mesvinian), I tentatively suggested this 'might well be the precursor of the Mousterian', and that it pointed to the existence of different races and cultures living contemporaneously together during the Palaeolithic period. Much light has since been thrown on this aspect of the subject, for which I would refer the reader to 'Man the Tool-Maker' by K. P. Oakley (1949).

I would only add that the three main types of the nodule-tools (chopper, pointed and axe-edged), together with the discs, flake-discs and polyhedric missiles, are also found in the Neolithic. Whether these may be an actual survival of a Clactonoid tradition, or an independent invention, is not so easy to say. I am convinced that the correspondence between Clacton and the early pebble- and flake-tool industries of tropical countries is too close to be of independent origin under the primitive conditions of those times. With the more advanced flint workers of the Neolithic, such simple tools might more easily be made independently for rough purposes, so it is difficult to reach a decision.

22. APPENDIX

ANALYSIS OF THE CLACTON INDUSTRY

	%
Biface group (*developed pebble-tools, etc.*), 8% approx.	....
Pointed form (the proto-boucher)	2.0
Axe-edged (mainly, with a few axe-shaped)	1.0
Choppers	3.0
Discoidal forms, probably missiles	1.2
Flake-discs, probably missiles	1.0
Polyhedric forms with jagged points, probably missiles	0.5
Trimmed Flake group, 5% approx.	....
Flake-points (proto-Mousterian flake-points)	0.2
Bill-hook form, typical	0.7
,, ,, ruder and less typical	0.3
Side-scrapers, straight-edged	1.6
Scrapers, segmental, elliptical, etc.	0.3
,, bulb- or butt-end	0.5
Slightly trimmed, form indefinite	1.0
Piercers and small flake-points	0.4
Sub-crescent forms (both core-crescent and flake-crescent)	2.0
Core group, 20% approx.	....
Casually chipped nodules	12.0
Cores with parallel flaking from platform	7.5
Flake group, 61% approx.	....
Outside spalls	15.0
Other spalls (about 8% of these are corner)	23.0

	%
One-edged flakes ...	17.3
Two-edged flakes, unsymmetrical	4.0
„ „ symmetrical blades ...	1.5
Abraded derivatives (?), mixed types ...	3.0
Anvil stones	1.0
	100.0

The basis for the frequencies given above for the various types of the Clacton industry was obtained from 373 flaked flints dug out of the Lion Point deposit without selection, the relative frequencies of the subdivisions being modified where a comparative study of the general collection showed this to be necessary.

Specimens chosen for illustration. In order to save space, I have, as far as possible, chosen small examples of the different types for illustration. Many of these I regard as child's sizes. Among primitive peoples it is the custom to make small sizes of their implements for their children, while the children in turn soon begin to make small implements for themselves. How far these should be regarded as toys, or as small useful tools for small fingers must be a matter of conjecture.

All the drawings except No. 29 (which is one-third) are shown half-scale linear.

ACKNOWLEDGMENTS

It only remains for me to express my thanks to Dr. K. P. Oakley for much valuable help, particularly for arranging a special exhibit of Clacton discoveries at the British Museum (Natural History).

In conclusion let me say how greatly I value the honour the Geologists' Association has conferred upon me in this award of the Henry Stopes Memorial Medal.

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THE DECOMPOSITION OF IRON PYRITE FROM COAL SEAMS

By ARTHUR BRAY, M.Sc., A.I.M.M., F.G.S.

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CONTENTS

		PAGE
1.	Introduction	136
2.	The Products of Decomposition	136
3.	The Disintegration of the Coal by Crystal Growth	139
4.	The Formation of the Secondary Minerals	139
	Explanation of Figure	139

SUMMARY.—The process of decomposition of iron pyrite to sulphates is described. The stages are progressive, from single needle-shaped crystals to tufts of ferrous sulphate crystals, which are characterised by curved shapes extinguishing as a whole between crossed nicols. Sulphuric acid is produced which usually prevents further oxidation. Where further changes occur, nodular growths of ferric sulphate are produced.

1 INTRODUCTION

In 1941 the writer presented a paper (*Proc. Geol. Assoc.*, **53**, p. 183) to the Association on the occurrence of iron pyrite in coal seams. The specimens described were subsequently housed in drawers in the geological museum of the Wigan Mining and Technical College and left undisturbed. A re-examination of the material showed that the specimens were in various stages of decomposition, ranging from unaltered pyrite to a crumbled mass of sulphate mixed with disintegrated coaly material. The changes were entirely due to weathering and crystal-growth, as the specimens had not been moved. The humidity of the room, where the specimens are stored, is usually about four grains of H_20 per cubic foot and the temperature is about 15° C. (*i.e.*, a relative humidity of approximately seventy per cent). A few specimens of massive nodular pyrite had resisted decomposition but this was probably due to failure to absorb moisture rather than to a difference in composition.

2. THE PRODUCTS OF DECOMPOSITION

The first indication of decomposition of the pyrite is the growth of single, needle-shaped crystals at right-angles to the surfaces of the specimens. In many cases these crystals are over half an inch long, are flexible and vary from .004 mm. to .008 mm. in width. A nodule several square inches in area may support only one or two of these needle-shaped crystals and exhibit no other indication of change. In a more advanced stage, the crystals are more numerous and grow out in tufts or sheaves, each sheaf growing out from a common location (Fig. 1a). The sheaves do not usually radiate outwards, but grow in

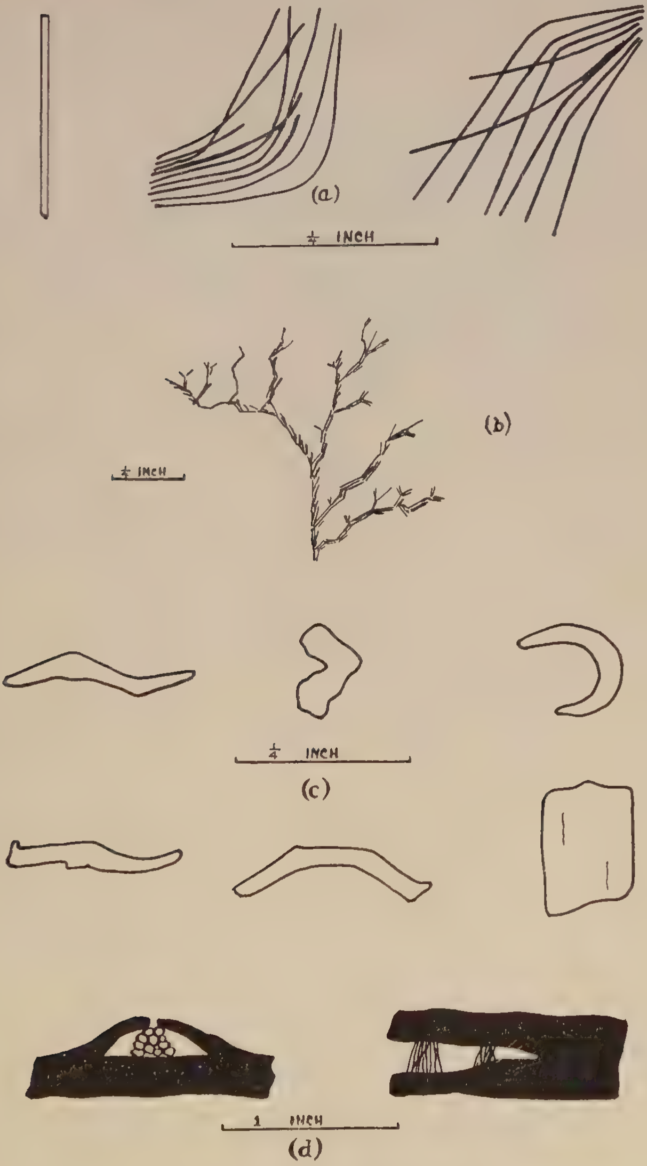

FIG. 1.—Types of iron sulphate crystal-growth in coal.

the same direction at right-angles to the surface on which they are forming. A characteristic feature is that the crystals usually bend to form an elbow about half way along the fibres. The sheaves often grow from isolated widely spaced centres, but in the more advanced stages of decomposition, the centres of crystal growth are close together, giving the appearance of a white mould growing on the surface of the pyrite. The crystals seems to grow best on the surfaces of the coaly layers surrounding or intermixed with the pyrite. In a polished specimen, which showed bands of coal adjoining streaks of pyrite, the sulphate crystals were restricted to the coaly portions. This may be due to the greater absorption of moisture by the coaly substance. With further growth, the crystals may coalesce and form single crystals which are transparent and frequently curved into fantastic shapes; where free growth is possible, the crystals are almost always curved into eliptical shapes. (Fig. 1c).

Under the microscope, the sulphate crystals show a refractive index below that of Canada balsam. Rectangular shapes are not common, but boomerang shapes are characteristic. The whole area of these curved crystals extinguishes between crossed nicols at the same time, so that in spite of their shape, all portions must have the same orientation. The extinction angles of the curved crystals are difficult to measure. It is probable that the crystals are hydrated iron sulphates of slightly different compositions.

A chemical examination of these crystals by Mr. W. B. Shaw indicates that they consist almost entirely of ferrous sulphate ($FeS0_4$. 7 H_20). When heated at 90°–95° C. for several hours the loss of moisture was 35.6 per cent by weight. A sample of known $FeS0_4$. 7 H_20 under the same conditions lost 36.7 per cent. A high proportion of the first formed crystals is, therefore, probably hydrated ferrous sulphate.

Where pyrite altering to sulphates is kept in cardboard trays, the card often becomes acid-stained and burned, and dendritic growths of white sulphate crystals form on the outside of the trays at a distance from the specimens. These dendrites are up to a square inch in area and are formed of tufts of white needle-shaped crystals growing end to end in a zig-zag manner (Fig. 1b). It is evident that the sulphate solutions can migrate away from the source of supply and later crystallise, for example in the coaly layers adjoining iron pyrite.

In addition to the hydrated ferrous sulphate crystals, which are by far the more common result of decomposition, there are isolated nodular growths of hydrated ferric sulphate. These growths are brown, white or green in colour and about an eighth of an inch in diameter. They may further alter to a soft yellow powdery material which resembles a yellow mould on the surface of the pyrite. The hydrated ferric sulphate is more usually found in the coaly substance rather than on the pyrite itself. Somewhat exceptionally, needle-shaped crystals of hydrated ferrous sulphate may grow out from the top of the nodular ferric sulphate.

3. THE DISINTEGRATION OF THE COAL BY CRYSTAL GROWTH

Where coal and pyrite occur together in conditions under which oxidation can take place, there is a marked and well-known tendency for the coal near the pyrite to disintegrate. The coal first opens along fissures parallel to the banded constituents and the fissures are occupied by patches of sulphate crystals growing across. The growth of the crystals completely disintegrates the coal, which eventually crumbles to a mass of crystals intermingled with coal fragments. The vitrain is usually more prone to disintegration than the other banded constituents probably because it is more crossed by fine cracks. The nodular growths of ferric sulphate are also effective in disintegration of the coal and they may push up layers of coal as shown in Fig. 1d. Where they grow in the cleat-fissures they may break off fragments of coal along the cleat.

4. THE FORMATION OF THE SECONDARY MINERALS

The first essential in the development of secondary minerals from pyrite is a source of water, either as liquid or as water vapour. Absorption of moisture leads to the production of what is apparently a varied series of hydrated ferrous sulphate crystals and sulphuric acid. The solutions may migrate, and crystallisation may take place some distance from the original source, very often in small fissures in the coaly layers. Normally ferrous sulphate rapidly oxidises to ferric sulphate, but the presence of free sulphuric acid in the vicinity of the hydrated ferrous sulphate crystals prevents this, so that the end product of pyritic decomposition is more usually ferrous rather than ferric sulphate. In shale tips at the surface, ferric sulphate is fairly common, due to the washing out of the sulphuric acid.

The alteration of pyrite to hydrated ferrous sulphates can go on very rapidly, and, under favourable conditions, can take place in a few hours.

EXPLANATION OF FIG. 1

(a) Needle-shaped crystals showing typical bending.
(b) Dendritic growth of sulphate crystals.
(c) Typical shapes of hydrated ferrous sulphate crystals. The whole crystal extinguishes in one position.
(d) Coal broken by crystal growth. At the right a nodular growth of ferric sulphate has arched the band of coal. At the left crystals of ferrous sulphate have split the coal.

STUDIES OF THE DEVONIAN AND CARBONIFEROUS OF WESTERN EUROPE AND NORTH AFRICA

By PROFESSOR G. DELÉPINE

[*Received* 20 *June* 1949]

CONTENTS

PART I.—Comparative stratigraphy of the Carboniferous marine formations of North-west Europe and the Mediterranean area.

PAGE
1. FRANCO-BELGIAN AREA 141
2. ARMORICA 143
3. CENTRAL MASSIF 146
4. VOSGES 146
5. MONTAGNE NOIRE AND PYRENEES 146
6. ASTURIAS 147
7. NORTH AFRICA 150
   (a) Morocco 150
   (b) Djerada 150
   (c) Colomb-Bechar–Kenadsa 150
   (d) Tafilalet 151
   (e) Sahara 153

PART II.—Movements of the late Palaeozoic Seas—Devonian and Carboniferous—in Western Europe and North Africa.

1. GENERAL PHYSIOGRAPHICAL CONSIDERATIONS 154
2. MOVEMENTS ON THE SOUTHERN BORDER OF THE ARDENNES, DURING DEVONIAN AND CARBONIFEROUS TIMES 155
3. AMORICAN MASSIF: BRITANNY–ANJOU–VENDÉE 157
4. THE CENTRAL PLATEAU 159
5. ASTURIAS 160
6. NORTH AFRICA 161
7. CONCLUSION 165
   ACKNOWLEDGMENTS 165
   REFERENCES 165

SUMMARY:—

PART I.—Following a brief comparison of the British and Franco-Belgian developments, the variable facies-development in the synclinal belts as traced through Armorica, the Central Massif and the Montagne Noire–Pyrenean region, is discussed. Further south, the development in the Asturias is related to the Moscovian province, while the faunas of the North African outcrops are shown to be related to those of North America.

PART II.—A synthesis of the data for the repeated advances and retreats of the seas from the Mediterranean region across the Massifs of West Europe is given. Similar movements also took place in Asturias and North Africa, and it is concluded that the major Massifs delineated in Caledonian and Pre-Cambrian times, have operated as positive units from early Devonian times onwards.

Part I.—Comparative stratigraphy of the Carboniferous marine formations of North-west Europe and the Mediterranean area

THIS subject has been dealt with by many geologists in England, for example, fifteen years ago, by R. G. S. Hudson and J. Selwyn Turner 'Correlation of Dinantian and Namurian in West Europe' (1937). Consequently, I shall not stress here the marine Carboniferous of the British Isles, *i.e.*, the Mountain Limestone, the Yoredale Series and Millstone Grit, these latter now more often called Namurian (Jongmans, W. J., 1928, p. xliv).

1. FRANCO-BELGIAN AREA

In comparing the British succession with that of the Franco-Belgian Basin, I only want to point out the following differences:

(1) The general succession and characters (palaeontology and petrography), taken as a whole, are the same in the south-west province of Britain as in north France or Belgium; on each side the Namurian is poorly represented, if we look at it in the light of the British north-west province where the Namurian has a magnificent development. But there is one obvious difference: the Waulsortian is practically not represented in the south-west province, at least not by huge masses; one has to go to Ireland to find it.

What is understood by Waulsortian? It is a reef limestone made of fine grained calcareous mud, crinoidal debris, and even cherty beds here and there; but the main part is composed of massive unstratified limestone, with blue or black 'veins'; the central part of these veins consists of a great variety of fenestellids. These are interwoven, thus constituting a web on which calcium carbonate, coloured by manganese or iron oxides, was precipitated. These blue and black veins form a sort of net, in the mesh of which there may occur an abundance of fossils—brachiopods, lamellibranchs, gastropods and cephalopods, but no corals, apart from an elongated form of *Amplexus*. The difference between a Waulsortian reef and what is commonly called a knoll-reef in the Pennines is that the latter, as a rule, does not possess the net of black or blue fenestellid veins. But in each case 'these masses of limestone have caused local elevations on the bottom of the Carboniferous sea. Generally the adjacent rocks, below, above, and in lateral continuation are dark, thin-bedded and argillaceous' (Dixon, E. E. L., 1921, p. 58).

The distribution of the Waulsortian reefs (Fig. 1) is difficult to explain in view of our actual knowledge of growing reefs. They exist in Belgium over a large area: thirty miles east and west of Dinant, ten miles from north to south. They have a still larger extension in Ireland. They are known also in western France and near Vichy. In the knolls of the north of England, near Coplow for instance, there

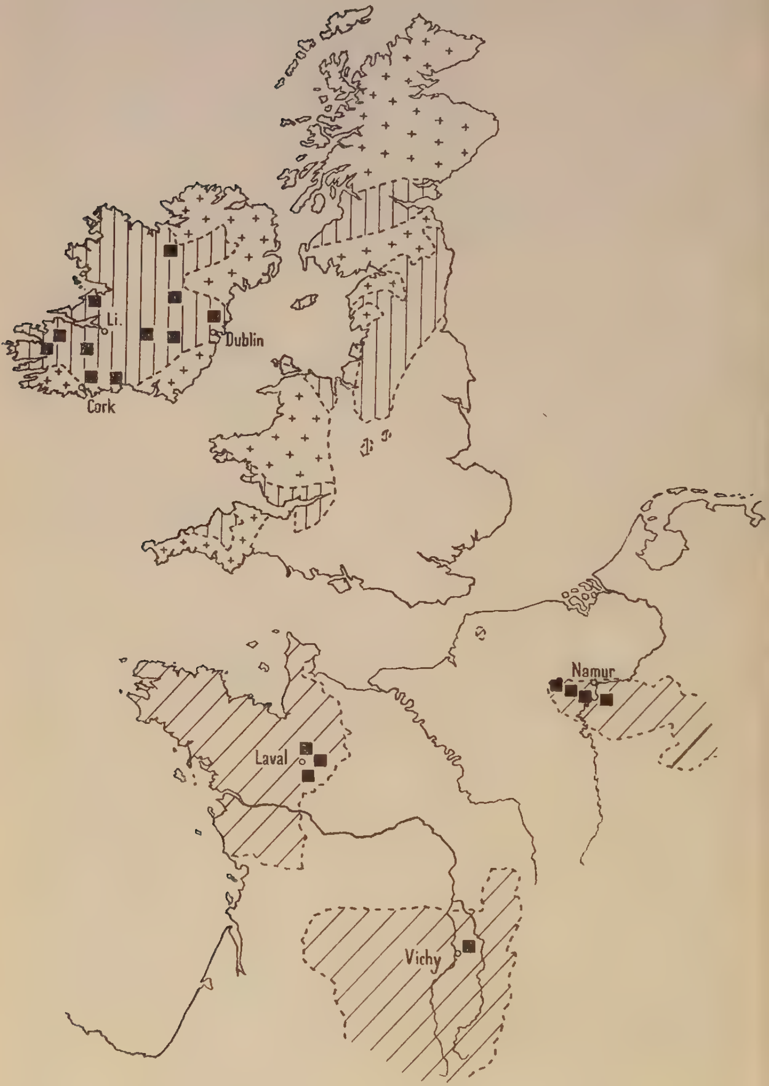

FIG. 1.—Distribution of Waulsortian reefs in north-western Europe. Black quadrangular spots indicate groups of Waulsortian reefs. Vertical lines indicate Carboniferous areas. Oblique lines indicate Palaeozoic massives.

are a few patches of true Waulsortian veined limestone (Parkinson, D., 1935, p. 100).

(2) Another difference is the big development of algal beds as shown by Garwood in the north-west province. Their area was extended progressively northward as the sea advanced through Westmorland and Northumberland towards Scotland. *Solenopora*, *Ortonella*, *Girvanella*, *Mitcheldeania* and *Bevocastria* are the main, and more or less locally developed genera.

As far as I am aware, such an important development of algal limestone is unique in the Carboniferous of Europe. Since it was first described, algal beds have been sought everywhere and found to a small extent in the south-west province (Reynolds, S. H., 1921, p. 227) and in Ireland (Turner, J. S., 1937, p. 193). In Belgium, where they occur in the great breccia, it is found as a peculiar brecciated limestone of D_1 age.

Garwood (1912 and 1931), by drawing attention to the presence of algae in the Carboniferous Limestone on the whole northern front of the Pennine Chain, added new ideas to stratigraphy. Extensive algal beds mean a moving sea, actively transgressing on a subsiding continental shelf.

(3) In the 'continental' Carboniferous formations—the Coal Measures—there is a difference between Britain on the one hand and north France and Belgium on the other in that the marine bands are more numerous in north England. On the other hand they are still more abundant, and often more important, in eastern Europe and in Germany than they are in the British area. This observation, a very early one in the study of the Carboniferous, shows that during the Westphalian, when a general subsidence occurred in north-west Europe, the sea came from the east, exactly as happened later during Permian and Triassic times. This suggests that, southward, connection was not so easy, the northern border of the Mediterranean Sea not being widely open to communication with north-west Europe. If not a large continental shelf, at least a cordillera existed between our north-west regions and the so-called Mesogea and a large Mediterranean sea existing during Carboniferous times. The study of west and central France will show that such a barrier existed.

2. ARMORICA

In west France (Britanny, Normandy, Anjou) the outcrops of the Carboniferous formations are not continuous: they are distributed from north to south in narrow synclines, their axes being east–west or south-east–north-west. Moreover, differences exist from one to the other in thickness and in petrographical characters, as if the sedimentary conditions had been different. This suggests that the bottom of the sea might have been rendered uneven by movements and deep rooted folding in operation during early Dinantian times.

Syncline of Régneville-Montmartin: The lower part, lying on Pre-Cambrian, is made of red conglomeratic material and shales, which have long been considered to be of Cambrian Age (*poudingue pourpré*). On this view the upper beds of Cambrian or Silurian age, so well exposed near May (south of Caen), have here been eroded or cut out by a fault. But it appears more likely now, that these red conglomerates and shales are the basal beds of the Carboniferous, and that their red colour originated from the weathering of some eruptive rocks, dolerites for instance; for such eruptive rocks are met with at the bottom of the Dinantian in many other synclines. Above the *poudingue pourpré* there abruptly comes in pure limestone with big *Daviesiella comoides* and *Chonetes carinata*—the same as the Arnside fauna in Furness, of Lower Visean age. There is nothing else in this syncline.

Laval Synclinorium: At Laval, the basal formation is a rhyolite, called blavierite, above which are shales and sandstones, mixed with crushed anthracite (all this being perhaps of C_1 age) and finally limestone. This, the 'Sablé limestone', contains a fauna with big *Daviesiella comoides* again, large specimens of *Caninia*, very large examples of *Syringothyris cuspidata*, clisiophyllids, and, a little higher up, carcinophyllids and *Lithostrotion irregulare*, this latter here coming in S_{1-2}, as in the north-west province. I must mention also Waulsortian reefs, in two different places, one west of Laval, at St. Pierre-la-Cour, on the way to Vitré and Rennes; the other at Bouëre, west of Sablé, in a small syncline on the southern border of the Laval synclinorium. But except at this locality, Bouëre, in the southern part of the synclinorium, the limestone is mainly a white oolite with *Linoproducti* of the *cora-* and *hemisphaericus*-groups. Over the limestone, there is greywacke with latissimoid and punctate *Producti*; finally these beds are overlain by argillaceous limestone or shales which are continuous from the top of the Visean to the Lower Namurian (Laval Shales).

Angers–Ancenis Synclines: In these, no Carboniferous formation with marine fauna is known. Thick shales with plant remains, prevail. These Bureau (Bureau, E. and L., 1910, fasc. 1) divided into two series, the Lower and Upper Culm, the latter certainly Namurian, the former of Visean age, and not lower Tournaisian, as was published after the Heerlen Congress (Carpentier, A., 1928, p. 136). The bottom of this Lower Culm is made of red shales, a relic of an eruptive layer. Barrois (1886, p. 202) expressed this opinion because, in the Châteaulin syncline in Britanny, the bottom beds of the Dinantian are everywhere green and reddish shales which are really in part ashes and small fragments of dolerite. In the Châteaulin syncline the age of the shales with plant remains could not have been fixed, had not Prof. Milon (Milon, Y., 1923, p. 592) collected from a small patch of limestone, at St. Segal (Finistère), a fauna with *Productus giganteus*, *Lonsdaleia* and dibunophyllids, all pointing to an Upper Visean age. This leads us to think that, in spite of appearances, the shales with plant remains of the Lower Culm of Ancenis and Angers might be a marine formation. Nowhere have fresh-water fossils been collected from it, and in this respect it differs from the Upper Culm. This latter is resting uncomformably on Devonian, or even on crystalline rocks. In it scales of fresh-water fish, tiny crustaceans, *Leaia* and ostracods have been found north of Sablé. This fauna shows that these Upper Culm beds are equivalent to the Millstone Grit and even to the Lower Coal Measures. As a matter of fact some coal seams were worked again there during the 1939–45 war.

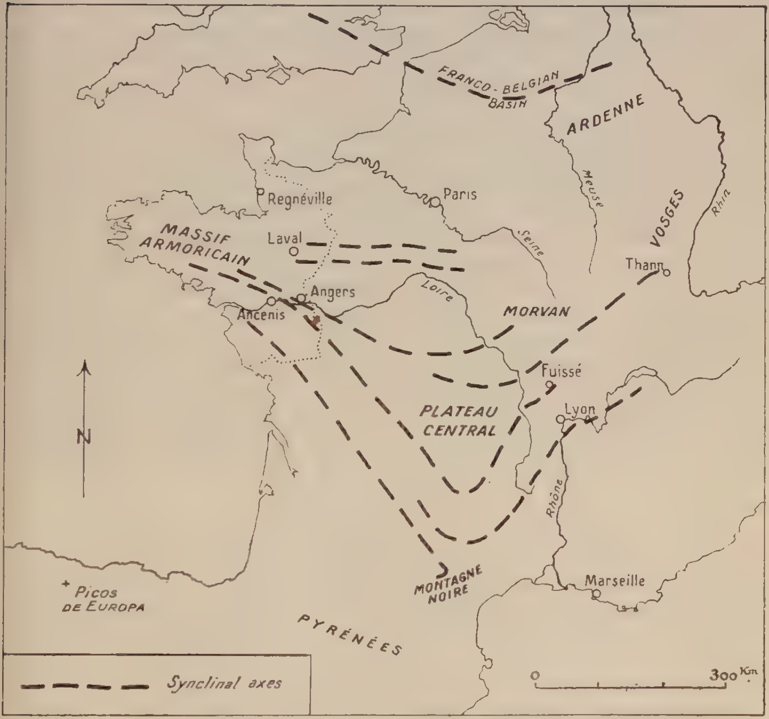

FIG. 2.—Map showing relationship between the Carboniferous synclines in Armorica, Central Plateau and Vosges.

Every one of these synclines is to be found again in the massif of the Central Plateau; if one follows them on the maps (Fig. 2) one sees their directions change all at once in the middle of the massif, from south-east to north-east, and they succeed one another from north to south on the eastern border of this large crystalline and metamorphic region of the central part of France.

3. CENTRAL MASSIF

In the north there are the continuation of the Norman and Laval synclines. In Morvan, oolitic and foraminiferal limestones are developed, as near Sablé, overlying anthracolitic conglomerates and grits with rhyolites. Near Vichy, C_2 limestones contain patches of Waulsortian bryozoan reefs; the uppermost beds being greywacke with latissimoid *Gigantellae*. At Fuissé, near Macon and Lyon, there are shales with a well-preserved flora, the species being the same as those known in Moravia (eastern Europe), amongst shaly beds containing *Goniatites crenistria* and *G. striatus*, undoubtedly Upper Visean. This 'Fuissé flora' is exactly the same as the flora of the Lower Culm of Ancenis. We can, therefore, establish the connections of these formations from one syncline to the other.

4. VOSGES

If we look eastward, the south-west–north-east direction of folding in the Central Massif leads us to the Thann area, in the Vosges. Here occur anthracolitic beds and greywacke, the so-called greywacke of Thann, with the same Upper Visean fossils as near Vichy (l'Ardoisière) and at Sablé—*Linoproducti* of the *cora*- and *hemisphaericus*-group, *Gigantellas*, punctate *Producti*, etc.

It is clear, then, that from the extreme west of France (St. Segal) to the extreme east, in the Vosges, one can trace the succeeding basins of sedimentation—limestone here, greywacke there, or shales with plant remains with very shallow water, or neritic conditions prevailing.

Now, south of this geanticline (Britanny-Central Massif–Vosges) one reaches the northern border of the large Mediterranean geosyncline. The outposts are the Montagne Noire, the Pyrenees, and, far to the west, Asturias (see Fig. 2).

5. MONTAGNE NOIRE AND PYRENEES

We meet here with quite different kinds of sedimentary rocks: in every section, the basal Carboniferous beds rest on Upper Devonian which may be Frasnien, sometimes Famennian—even the uppermost. These basal beds are lydite, *i.e.*, silicified shales, with a variable amount of phosphatic nodules, sometimes in such quantity to be worked as, indeed, they have been until recently. They are found all along the northern front of the Pyrenees and also in the Montagne Noire (Cabrières, St. Nazaire de Ladarez). What is most remarkable is the fauna that one is able to extract from these nodules: radiolaria, goniatites, crustaceans (Phyllopoda), fishes, pieces of wood with structure magnificently preserved, and *Lepidostrobus* (seed cones). The goniatites are: *Pericyclus fasciculatus*, *P. kochi*, *Aganides ornatissimus*, *Munsteroceras*, *Protocanites*—altogether sufficient to indicate that we are there near the limit between Upper

Tournaisian and Lower Visean. The equivalents in north-west Europe are the *marbre noir* of Dinant and Bachant (the oolite with *Productus sublaevis*). Above the lydite comes a 'griotto limestone' (concretionary beds, red and violet coloured); the typical locality is Faugères. Here the goniatites include: *Merocanites applanatus*, *Pericyclus hochecornei*, *P. kochi*, beyrichoceratids, indicative of S_1–S_2 level and probably the equivalent of the Erdbach-Breitscheid Limestone in Germany. Higher up come shales and thin sandstone layers with plant remains and finally the 'Larbont Shales' (Ariège) with *Gigantellae*. South of St. Girons this whole formation is capped by the 'Mondette Shales' with *Goniatites striatus*, *G. subcircularis*, *G. granosus*, *Pronorites cyclolobus* and *Daraelites praecursor*—the last not the least important, for the presence of the genus *Daraelites* gave rise in 1903 to a very big mistake. That genus of goniatite being considered of Permian age, all the rest were disregarded, and the story of marine Permian beds existing in the Pyrenees has been accepted and is still found in many geological books[1]. But Fromaget had long before found *Daraelites* in Upper Visean beds with *Productus giganteus* in Indo-China. Later on Kobold found it from the same level in Germany. The old legend of marine Permian in the Pyrenees has to be abandoned entirely. One has to go as far east as Sicily and south Tunisia to get Permian beds with a marine fauna.

In the west Pyrenees Lower Namurian shales pass up without any break into the 'Subcircularis Beds'. We find here, west of St. Jean-Pied-de-Port, *Eumorphoceras bisulcatum* and *Stenopronorites uralensis*, which have also been found since in North Africa. The top of the formation is a black, somewhat magnesian limestone—and that introduces to us in Asturias, north-west Spain, a quite different type of marine Carboniferous of Upper Dinantian, Namurian and Westphalian ages, or better called, in this case, Moscovian.

6. ASTURIAS (see Fig. 3)

West of the Pyrenees, through Biscaye, the Palaeozoic formations are buried; the surface, the mountains as well as the plateaux, are mainly Cretaceous, with here and there some Triassic or Jurassic. Only west of Santander, in Asturias and Galicia, do the Palaeozoic rocks crop out again in the high mountains called Picos de Europa. A big development of limestone extends in every direction, as far as west of Oviedo, encircling small patches of black shales with very thin coal seams. Only south of Gijon and Oviedo does the Sama basin (Mieres) provide the country with something comparable in importance to the English and Franco-Belgian Coal Measures. Barrois, who worked out the Carboniferous marine formation in Asturias,

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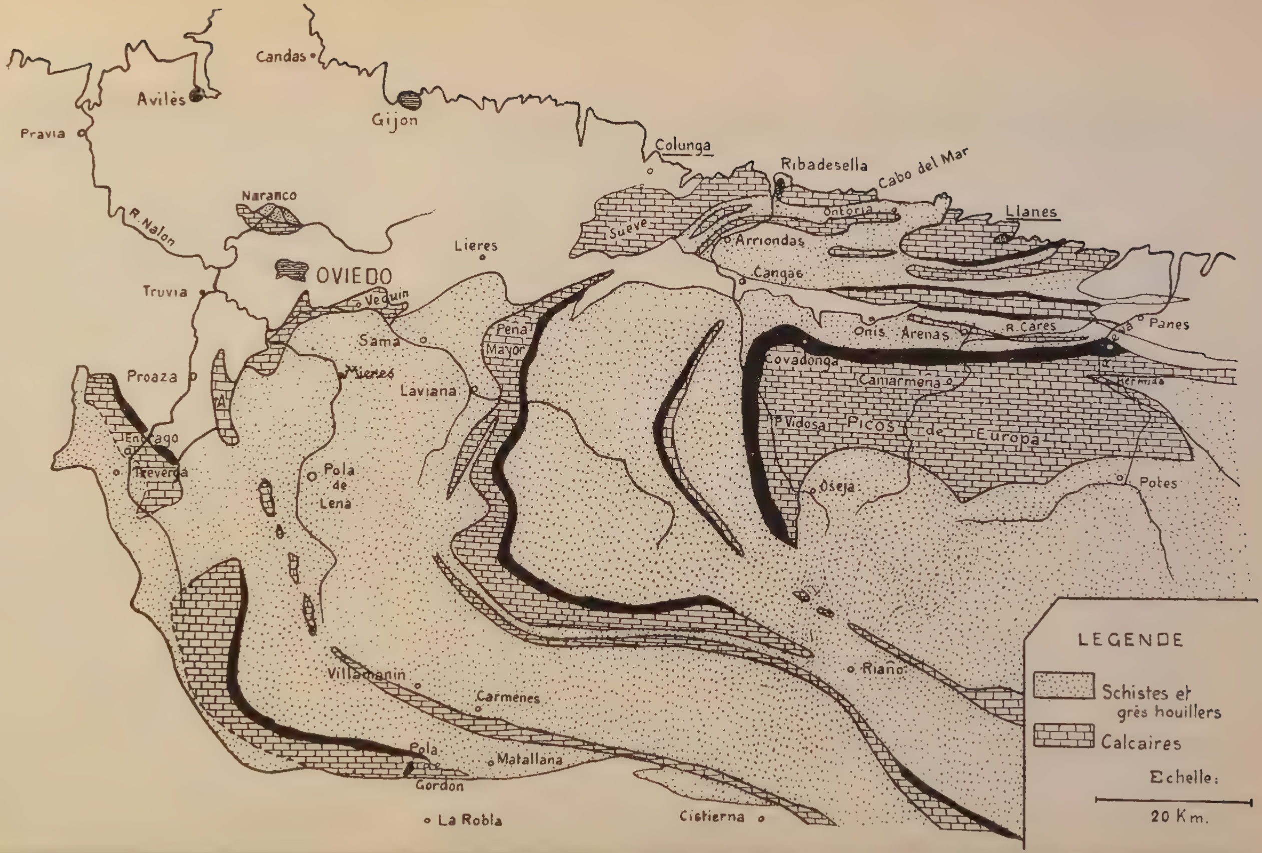
[1] For instance, Hermann Schmidt in 'Das Paleozoicum des Spanishen Pyreneen' (1931); and it has found its way to America where it has been repeated by A. K. Miller (1933, p. 424) referring to H. Schmidt.


Candas
Avilès
Gijon
Pravia
Colunga
Ribadesella
Cabo del Mar
Naranco
R. Nalon
Sueve
Ontoria
Llanes
Arriondas
Lieres
OVIEDO
Cangas
Truvia
Vequin
Sama
Peña Mayor
Onis
Arenas
R. Cares
Panes
Proaza
Mieres
Laviana
Covadonga
Camarmeña
Hermida
Entrago
Teverga
Pola de Lena
P. Vidosa
Picos de Europa
Oseja
Potes
Riaño
Villamanin
Carmenes
Pola
Gordon
Matallana
La Robla
Cistierna
LEGENDE
Schistes et grès houillers
Calcaires
Echelle:
20 Km.

gave the following succession, and correlation with the Franco-Belgian basin (Barrois, C., 1882, p. 584–91):

Stephanian.
Sama beds = Lower and Middle Westphalian.
Lena beds = Upper Visean.
Cañon limestone = Waulsortian and Lower Visean.
Griotto = Tournaisian.

This Carboniferous succession has been revised since (Delépine, G., 1943, p. 42), and the correlation has to be somewhat modified. As to the griotto, Barrois had recorded *Goniatites crenistria*, *Pronorites cyclolobus*, *Prolecanites henslowi*; but many other species have been collected since—*Goniatites sphaerico-striatus*, *G. falcatus*, *G. granosus*, *G. subcircularis*, *Prolecanites serpentinus*—all pointing to the highest level in the Upper Visean. These Visean beds rest to the west of Gijon on Upper Devonian, Frasnian or perhaps Lower Famennian; and on Upper Famennian sandstones and shales only in the Leon Province. West of Oviedo, the griotto were deposited on Middle Devonian ferruginous sandstones and coral limestones and east of Oviedo, on Silurian sandstone, the equivalent of the *grès armoricain* in Britanny, and the Arenig of Wales.

The Cañon limestone always comprises two series: the lower one, a black magnesian limestone, 600 feet thick, from which no fossil has ever been recorded; the upper, a white massive pure limestone, 1200 to 1500 feet thick, with *Fusulinella bocki* abundant all along the Asturias Mountains, from east to west and from north to south, in a foraminiferal band at a distance of 300 to 150 feet below the top bed. From the latter a fairly rich fauna of brachiopods has been obtained: *Proboscidella fasciculata*, *Marginifera pusilla*, *Pustulae spp.*, *Schizophoria plicata*, *S. resupinata*, *Reticularia lineata*, *Spirifer rockymontanus*, *Brachymetopus uralicus*. In the Lena Beds, limestone beds alternate with shales. The fauna is abundant: *Spirifer fasciger*, *S. strangwaisi*, *Marginifera pusilla*, *Productus cora*, *Stafella sphaeroidea* (Barrois) and higher up: *Fusulina cylindrica* and *Spirifer mosquensis*. Coal seams worked at Lieres and in part of the Sama Basin are present at many levels in these series.

The fauna establishes undoubted correlation with the Moscovian of Podolsk and Myatschovo. As to the correlations with north-west Europe, goniatites and nautiloids have been collected at Lieres: *Homoceratoides kitchini*, *Anthracoceras cambriense*, *Metacoceras postcostatum*. All point to a relationship with the marine fauna from the Upper Westphalian in north England, Scotland, Dutch Limburg and Germany (Fig. 4).

These Asturian faunas suggest also correlation with the Fusulina cylindrica Beds in Leon, Valencia and, further east, in the Carinthian Alps, the north of Hungary and, finally, the Moscow area. Asturia is the most western outcrop of the fusulinid limestone, a true Mediterranean facies quite unknown in north-west Europe. The continental phase comes in much later than in the latter region. With Coal Measures appear goniatite faunas of the Westphalian of north-west Europe. Therefore Asturias was the link in Carboniferous times between east and west. We shall see now that Asturias was also a link between north-west Europe and North Africa.

7. NORTH AFRICA (see Fig. 5)

Through Portugal, where Upper Tournaisian has been discovered, and Catalonia, where Upper Visean is well known (Papiol Shales), we reach the southern part of Mesogea through Morocco and the Sahara.

(a) **Morocco.** This can be divided into two parts, by a line from Meknes to Tafilalet (Erfoud). In the west part, the Meseta of central Morocco, the succession and facies, petrography and fauna, are the same as in the Franco-Belgian basin, from the Etroeungt (or Pilton Beds) to the Upper Visean: limestones, greywackes, and, in the Namurian, shales with plant remains [our Culm]. The Westphalian in the west is continental but without coal. In the east, there are two Coal Measures basins, one at Djerada, near Oujda, the other west of Colomb-Bechar at Kenadsa; they are separated by plateaux 3000 feet high and Djebels (mountains) called Dj. Horeit, Grouz and Antar, which are parts of the Great Atlas.

(b) **Djerada.** Rhyolites, resting probably on Silurian or Devonian rocks, are overlain by Gigantella Limestone of the same Upper Visean age as the griotto in Asturias. Above it lie 3–5000 feet of shales with thin layers of sandstone or conglomerate; only in the upper part do thin coal seams appear. The fauna is, as far as known, wholly marine with goniatites and brachiopods. No fresh water fauna is recorded from these levels, even in connection with the coal seams. In regular succession one can pick up along the road from Oujda to Colomb-Bechar, *Homoceras diadema*, *Reticuloceras*, *Gastrioceras listeri*, *G. stenolobum*, *Phaneroceras*, *Anthracoceras aegiranum*, *A. hindi*, *Metacoceras costatum*, and, in the highest beds, *Spirifer mosquensis* and *S. myatschovensis*. As in Asturias, again we are getting very high in the Moscovian. A more important conglomerate, with bigger pebbles, denoted H_3 by the local engineers, marks the introduction of a true continental phase, with six coal seams thick enough to be workable. The fauna is freshwater, and the highest beds contain a fauna (*Anthracomya*) and flora of Lower Stephanian age, without any apparent break with the beds below.

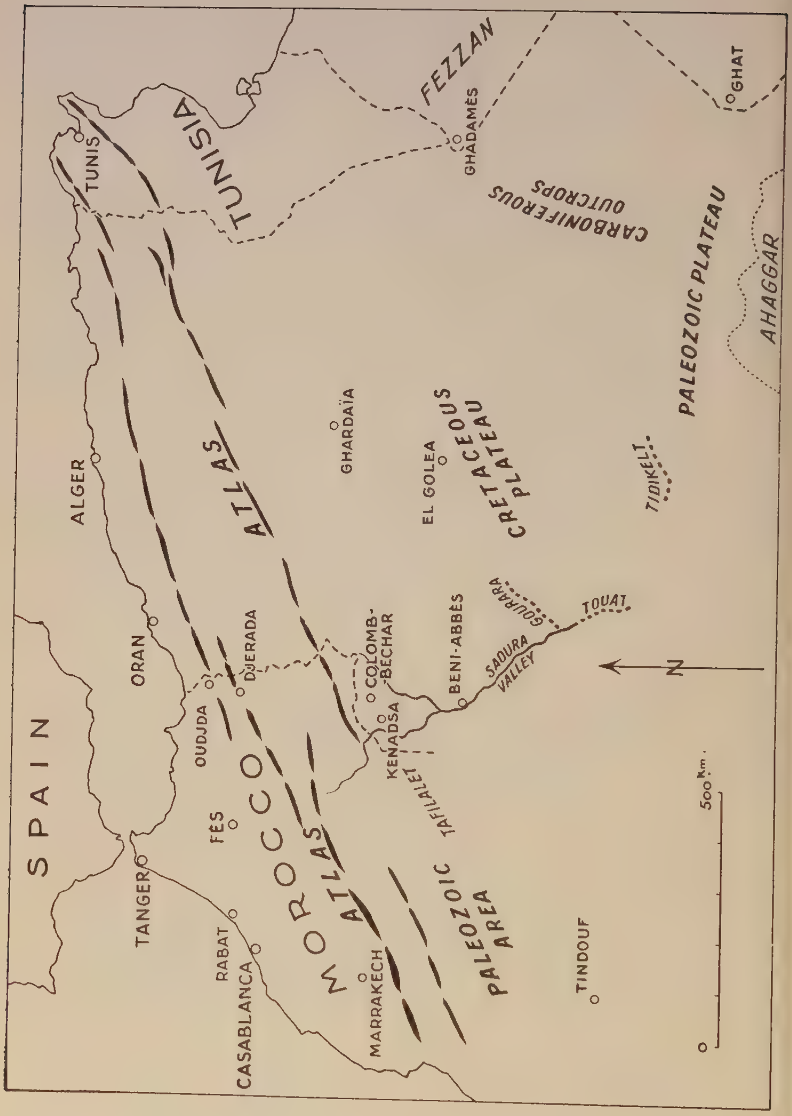
(c) **Colomb-Bechar–Kenadsa.** This region differs from the Djerada region with following particulars: well defined Upper Visean limestones and shales are followed by Namurian dolomites and limestones, with even coral limestone (with *Chaetetes*). From one shale and limestone bed I obtained *Reticuloceras*, which shows that these limestone beds are really Namurian, and not Dinantian as was supposed fifty years ago by Flamand. On the north front of Dj. Grouz and Dj. Antar, Menchikoff (1936, p. 131) has obtained, in limestone patches, *Homoceras striolatum*, big *Cravenoceras africanum*, *Proshumardites karpinskyi*, *Dimorphoceras thalassoide*? (known in the Pyrenees), *Stenopronorites uralensis* (Pyrenees). It is not only the names of the fossils that recall the Ural Mountains but also the facies, for, in the Shartymka Valley in the southern Urals, there is also an important limestone formation with brachiopods and goniatites of Namurian age. In the upper part of this Colomb-Bechar Carboniferous, shaly beds alternate with ferruginous limestone beds, fossils being sometimes coloured red by haematite. Brachiopods are spirifers of the *S. mosquensis* group and *Enteletes*, nautiloids include *Metacoceras* and *Ephippioceras* and there are numerous goniatites such as *Anthracoceras hindi* and *A. aegiranum*, indicating the upper part of the Westphalian; others are related to genera and species only met with in North America—*Proshumardites primus*, *Glaphyrites*, smooth gastrioceratids, *Bendoceras texanum* (a very big form), *Gonioloboceras* and a new genus *Eoparalegoceras*.

We shall have other instances of fossil species in North Africa which are the same, or are very nearly related to North American species, in the Devonian as well as in the Carboniferous. From the south of Colomb-Bechar there is access to the Saoura Valley. This is a north–south depression, 1,500 miles long, which corresponds to a zone of subsidence during Devonian and Carboniferous times. A goniatite facies was predominant from the Middle Devonian onwards.

(d) **Tafilalet.** The Tafilalet, 100 miles west of Colomb-Bechar, is included in the same area of goniatite facies. At Erfoud, the main oasis, nodules in green shales on the slopes of the old fort have yielded three successive goniatite bands. The lowest includes *Pericyclus fasciculatus*, *P. rotuliformis*, *Munsteroceras crassum* and *Nautellipsites hibernicus*, a fauna closely related to the Irish, and indicating a level near the limit between Tournaisian and Lower Visean. The other bands are undoubtedly Lower Visean with *Munsteroceras euryomphalum* (South Wales–Germany), and Upper Visean with beyrichoceratids and goniatites of the *striatus* and *falcatus* groups. The same Upper Visean fauna was collected near Taouz (eighty miles south) and a Lower Namurian one with *Anthracoceras paucilobum*, etc., at Derkaoua, half way between Erfoud and Taouz.

Altogether, in this part of North Africa (Djerada, Colomb-Bechar), we have evidence of two special characters of the Carboniferous formations:

(1) The continental régime comes in, as in Asturias, much later than in north-west Europe, as late indeed as the uppermost Westphalian.


SPAIN
TANGER
RABAT
CASABLANCA
MARRAKECH
FES
MOROCCO
ATLAS
OUDJDA
DJERADA
ORAN
ALGER
ATLAS
TUNIS
TUNISIA
FEZZAN
GHADAMÈS
GHAT
CARBONIFEROUS OUTCROPS
PALEOZOIC PLATEAU
AHAGGAR
GHARDAÏA
EL GOLEA
CRETACEOUS PLATEAU
TIDIKELT
GOURARA
TOUAT
BENI-ABBÈS
SAOURA VALLEY
COLOMB-BECHAR
KENADSA
TAFILALET
PALEOZOIC AREA
TINDOUF
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(2) The faunas are frequently related to the Russian and also to the North American.

(e) **Sahara.** Here I shall deal with occurrences in succession from west to east—(i) the Tindouf geosyncline; (ii) Tidikelt and Gourara in the centre; and (iii) the Fezzan in the east.

(i) *Tindouf.* Dinantian rests without break on uppermost Devonian. All the zones of the Dinantian, with brachiopods and corals, are known, and are the same as in north-west Europe. There is the same alternation of shales and limestone beds with shallow water or neritic conditions prevailing, as in central Morocco.

(ii) *Tidikelt and Gourara.* This was a subsiding area as in the Saoura Wadi. Goniatite faunas succeed one another all through the Upper Devonian, the Etroeungt level (Pilton beds), the Lower and Upper Tournaisian, and the Lower, Middle and Upper Visean. I think that when these faunas are described and figured—Meyendorf (1939, p. 200) has worked on them—they will fill many gaps in our knowledge of the goniatite succession, especially the one which exists between the Lower and the Upper Visean, between the last *Pericyclus*, *Munsteroceras* and *Merocanites* below, and the in-coming of beyrichoceratids and *Goniatites* s. str. above.

(iii) *Fezzan.* Here we again meet with neritic conditions, brachiopod and coral faunas. Some fifty years ago, Foureau-Lamy, while on a French military expedition, met with fossils which were then regarded as giving evidence of strata of Uralian age being represented there. This cannot be maintained: Menchikoff has since obtained a *Syringothyris*-bearing Upper Tournaisian fauna, from the sandstone of Serdeles (so called Devonian of Italian geologists) and, higher up, beds with *Productus giganteus*. In 1947, A. F. de Lapparent collected, from the same area and same levels as did the Foureau-Lamy expedition, a number of brachiopods and corals; we are now working on them and it appears that their age is probably Moscovian. This is related closely to all that has been observed in the west Sahara and Morocco: marine conditions existed not only during the Dinantian but until late in Westphalian, or Moscovian times. In the Fezzan, however, the most easterly of the outcrops, the change from marine conditions to a continental régime is represented not by the incoming of Coal Measures, as in the west and in Spain and Morocco, but by a series of gypsum and salt deposits alternating first with recurrences of shallow water marine limestone bands, and then deposits of red and green shales alternating with gypsum, and so on, until one reaches the covering beds of the Lower Cretaceous (also continental, for only the Upper Cretaceous are here marine).

Part II.—Movements of the late Palaeozoic Seas—Devonian and Carboniferous—in Western Europe and North Africa

1. GENERAL PHYSIOGRAPHICAL CONSIDERATIONS

All scientists interested in prehistoric times know that the bottom of the Channel, the Irish Sea and the North Sea have twice emerged since the end of the Pliocene. The shores of these seas were shifted as far north as Norway and Scotland, westward as far as a line from Finistère to Land's End. The British Isles were then a part of the Continent. During the Tertiary, the Paris Basin emerged in the Middle Miocene; but earlier, this same basin had been filled and then emptied twice during the 'Nummulitic'. The same had happened before, during the Jurassic and Cretaceous. The detailed study of the southern border of the Ardennes and the knowledge afforded by borings in the 'Pays de Bray', have shown that, in early Liassic times (Sinemurian) and at the beginning of the Aalenian, the Paris Basin emerged totally. This occurred again at the end of the Jurassic (Portlandian). Later, the sea coming from the south-east, during the early Cretaceous, again covered a very large area, greater than ever before during the Cenomanian and Turonian. Finally, a new retreat northward began in the middle Senonian.

Triassic and Permian times were each marked by a short transgression, seas coming from east of Europe, covering the German province and parts of east France and Britain. This carries us back to the Permian, at the end of Palaeozoic times.

The general impression to the geologist is that, during the Mesozoic and Cenozoic eras, geographical changes in north-west Europe, taken as a whole, have been slight. Continental shelves only emerged and, later on, were again covered by the seas, which generally encroached by the same routes via limited inlets and narrow straits, to fill large basins. Here and there were submarine ridges, more or less emergent so that islands of varying importance remained uncovered. These appear on palaeogeographical maps as an archipelago, the form of which changed very little during the period that elapsed between the Alpine and Variscan foldings.

What about earlier times, between the Hercynian and Caledonian tectonic revolutions, from the end of the Carboniferous back to the end of the Silurian? Was the geographical figure of our western Continent and North Africa quite different from what it was later on? To answer these questions I should like to review the evidence afforded by the extensive work of many geologists in the Ardennes, Britanny, South of France, Spain and North Africa.

2. MOVEMENTS ON THE SOUTHERN BORDER OF THE ARDENNES, DURING DEVONIAN AND CARBONIFEROUS TIMES (see Fig. 6)

At the beginning of Devonian times a large island, or shall I rather call it a continent—as it included the Ardennes and Brabant—extended westward through the Boulonnais to Britain, probably as far as Wales and eastern Ireland. To the south, the sea covered part of the Paris Basin, its shore extending from Charleville to the coal mining country of Lens, Béthune, the Vimy ridge (Barrois called it the Artesian Sea, 1912, p. 220), and further on, to north Devon, south Wales and south-west Ireland. From Gedinnian to Upper Coblenzian times, these seas gradually covered the massifs of Rocroi, Givonne and Stavelot, eroding the Cambrian and Silurian quartzites and sandstones to build huge masses of conglomerates seen at Montcornet, Fepin and Ombret, each one being at a higher level as the sea spread continuously northwards. But at the end of the Coblenzian, the forward movement was stopped along the outcrop of Silurian, called the 'Condroz Ridge', which extended from south of Liège,

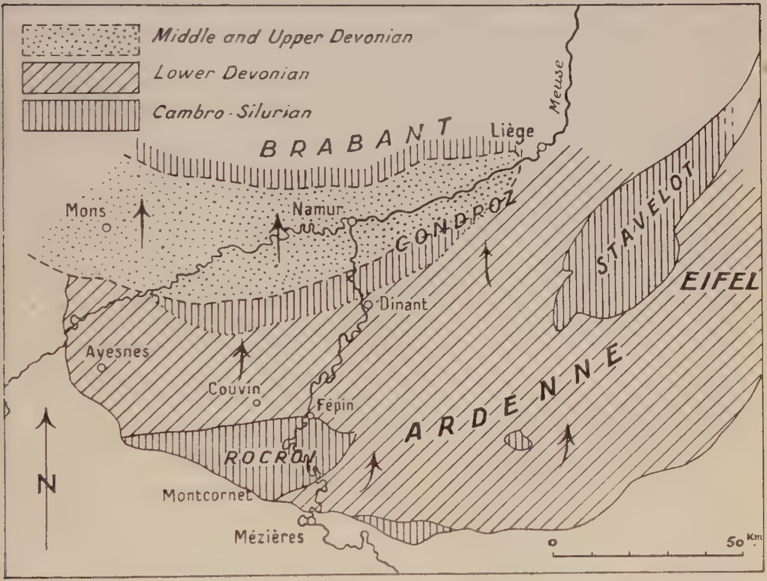

FIG. 6.—Map showing the areas covered by the Devonian seas in transgression over the Ardennes.

(1) Cambro-Silurian massifs.
(2) Area covered by the Lower Devonian transgression.
(3) Area covered during Middle and Upper Devonian. Arrows indicate the direction of the advancing seas.

Namur, Charleroi, Mons, and westward to south of the Boulonnais. There was even a movement of retreat, for red shales, fine grained conglomerate and sandstones (the Burnot Conglomerate and Shales), were deposited as far as Dinant and Givet. They give evidence of very shallow water, even shore line or estuarine conditions, and the fauna is somewhat related to that of the Old Red Sandstone.

The movement northward was resumed again during the Eifelian, when conglomerates of Tailfer, Naninne and Alvaux were deposited; each constituting a successive step from the southern to the northern border of the Condroz ridge and beyond, over the Silurian and the Cambrian of the Brabant. Henceforward there existed this new geosyncline known to geologists as the *Bassin de Namur* in the form of a trough that later on became filled with the richest Coal Measures. It ran east–west across Belgium and south-east–north-west from Lens to Boulogne. Middle and Upper Devonian beds, comprising shales, dolomite and coral limestones such as the well-known *Calcaire de Ferques* with *Spirifer verneuili*, were there the main deposits. Sedimentation had a decidedly neritic character. That was also the time (Givetian–Frasnian), when a remarkable barrier of coral reefs, still well seen in the actual topography from Givet to Trelon, existed through the classical districts of Couvin, Philippeville and Mariembourg. In the shales that were laid on the bottom of the inlets between the reefs, one can collect an extraordinary abundance of *Rhynchonella cuboides* and goniatites of the *Manticoceras*-group; and, exceptionally, a specimen of *Beloceras multilobatum*. Then all at once red shales again appear in the Namur Basin, even before the end of Frasnian times, followed by a thick series of sandstones, the bedding planes of which are typically strewn with mica. They are called the 'Condroz psammites', one of the typical Famennian facies. Their fossil content is similar to that of the British Upper Old Red Sandstone, with huge specimens of the dipnoian group such as *Palaedaphus* and *Heterosteus* with crossopterygians, notably *Holoptychius*, and also plant remains; this again means an uplift at the end of Devonian times.

Fully marine conditions were maintained only in the south, along a geosyncline which extended from south of Liège to Avesnes (north of France). There, muddy deposits and very fine grained sandstone prevail with occasionally a stromatoporoid limestone, in which one can find, in a continuous series of beds, a relict Upper Devonian fauna with new Tournaisian types such as semireticulate productids (*Dictyoclostus*-group) and *Spirifer tornacensis* with *S. verneuili*, as well as the last clymenias and Phacopidae. The in-coming of true Carboniferous species of brachiopods, is the first proof of a new and very important transgression, the Dinantian, which attained its maximum extension at the end of the Visean. Then, not only were the Ardennes covered again by sea, but also central and northern England, Scotland and all Ireland, with the exception of, perhaps, the

Wicklow Mountains. Basal conglomerate formations of Lower Visean age exist north of Dublin, also at Ingleborough and as low as C_1 on either side of the Pennine Chain. In Belgium, at Horion Hozemont, between Namur and Liège, Lower Visean limestones rest on Famennian; in deep borings west and north of Liège, and as far as Lierre and Woensdrecht, east and north-east of Antwerp, Upper Visean has been encountered. It is generally admitted that the seas of the Franco-Belgian Basin linked north Brabant as well as Kent and South Wales with the seas that covered the British Isles during the late Dinantian and Namurian.

3. ARMORICAN MASSIF: BRITANNY–ANJOU–VENDÉE

M. Pruvost[1] has summed up all the work done by Barrois and by himself on a sketch map that he has allowed to be reproduced here (Fig. 7). The main points are that two cordilleras were emergent from the end of the Pre-Cambrian era, one along the northern border of the massif from Normandy through the Channel Islands to Finistère, including regions which Pruvost calls Normania, Mancellia and Domnonaea, and a southern one from Finistère to Lorient, Nantes and Angers, called by Pruvost, Ligeria (after the River Loire). Normania was invaded as early as the Middle Cambrian—the limestone of Carteret with *Archaeocyathus* is of Acadian age; and a Postdamian transgression extended over all Ligeria. Later on, Mancellia subsided during the Arenigian but Domnonea not until early Devonian times, when the Gedinnian transgression began. Ferruginous sandstones with *Orthis monnieri* overlap formations from the Silurian to Pre-Cambrian in north and central Armorica. Lower Gedinnian is also represented by the Plougastel quartzites which form the conspicuous sierras of the 'Monts d'Arrhée', south of Morlaix and the ridges called Mené Hom and the 'Black Mountains' between Quimper and Pontivy. But the southern cordillera, the crystalline high plateau of Lanvaux, remained uncovered at that time and only much later in the Devonian was Ligeria included in a new general oscillation. In the meantime, during the Coblenzian, greywackes, resembling the Meadfoot Beds in Devonshire, were laid down in west Britanny, while limestones, even coral limestones, were deposited in the east, near Laval and in Normania (Nehou and Baubigny limestones). We shall see that the development of an important limestone facies in the *Lower* Devonian is a special Mediterranean character of the system.

In Mid-Devonian times, there was a *general uplift* of north and north-eastern Armorica, and sandstone and shales soon filled up the Laval Syncline. On the other hand, Ligeria was subsiding and the Lower Eifelian sea spread over the Ancenis Syncline. Here shales

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[1] P. Pruvost, 1949: Les mers et les terres de Bretagne, aux temps paléozoïques *in* Livre jubilaire Ch. Jacob, Annales Hébert et Haug, pp. 345–62 (published in 1950, since this synthesis was prepared).

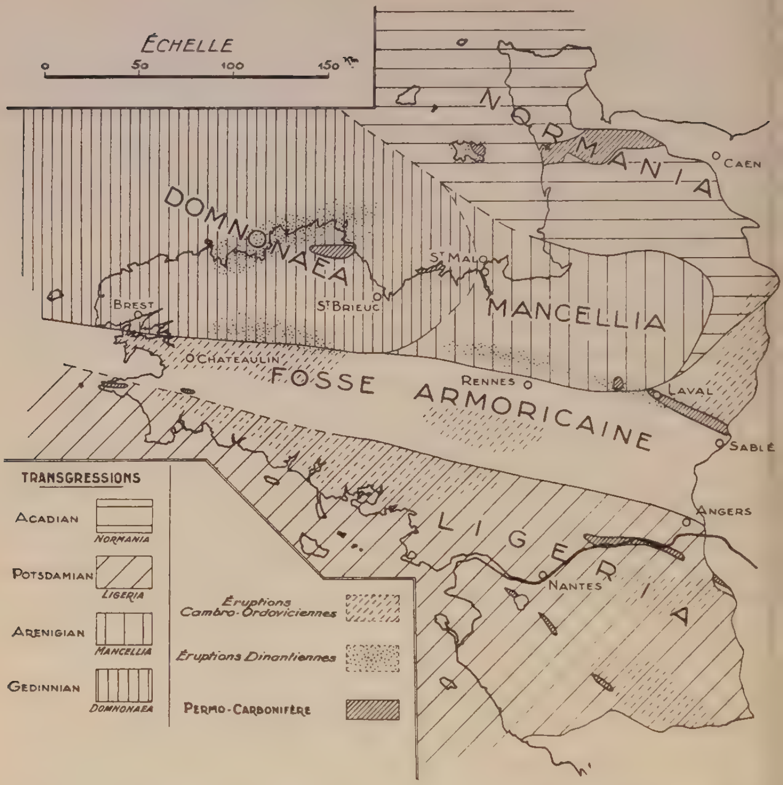

FIG. 7.—Movements of the seas in Armorica during early Palaeozoic (after P. Pruvost).

The arrows indicate the known limit of the seas in transgression from south to north during the Upper Devonian.

with plant remains and *Tentaculites* are soon replaced by masses of coral or brachiopod limestones, their fauna being related to the Bohemian Lower and Middle Devonian faunas of the Mnenyani and Konieprusy Limestones (Le Maître, 1934). A North American genus of brachiopod, *Amphigenia*, is found in this area and has since been recorded from the Austrian Alps, near Graz. These facts again point to Mediterranean relationships. In the upper Middle Devonian the uplift extended to the whole of Armorica. It seems that the sea retreated at that time as far as the Vendée province for Givetian formations and faunas are known nowhere in Britanny, nor in Anjou or Normandy. Near Niort, not far from Poitiers, there is, however, a quarry in coral limestone from which many good specimens of *Stringocephalus* *burtini*, the typical species of the Givetian, have been collected and recently figured.

After that, by limited advance, the sea moved again across the southern border of Armorica and in the west argillaceous deposits with goniatites, such as the Frasnian *Manticoceras* and Famennian *Cheiloceras*, were laid down as in Devon; in the east, a massive Frasnian brachiopod limestone (*Calcaire de Cop-Choux*) and a shaly limestone with Upper Famennian clymenias, are preserved in the tiny St. Joseph de Vouvantes Syncline north of Angers. Finally, general emergence (Bretonic faulting phase of Stille) ensued.

During the Carboniferous the whole Armorican massif subsided, eruptive rocks were ejected and Dinantian limestones and greywackes were deposited. Then came the Sudetian folding phase. The last Hercynian movements caused locally the formation of tiny continental basins with some workable Stephanian coal seams. From then on Armorica has been emergent for a very long time; only during the Tertiary did the sea invade that country again along the actual valleys of the Loire and the Vilaine.

4. THE CENTRAL PLATEAU

The history of the Central Plateau during the Palaeozoic era is not yet sufficiently known: large intrusions of granite and metamorphism have altered the characters of the formations. It can only be assumed that the Central Plateau as a whole was an uplifted area after the Sudetian folding phase.

We have, however, a more detailed knowledge of what happened south of the Central Plateau in the Montagne Noire and the Pyrenees. Their history seems to have been nearly the same as in Britanny: if not always the Gedinnian, at least the Coblenzian, exists everywhere, marked by greywacke or by coral and brachiopod limestone deposits. The Mid-Devonian seems often to be reduced to Eifelian. Frasnian includes *Manticoceras* limestone, and in the west Pyrenees sandstones with *Spiriter verneuili*. Finally Famennian all along the Pyrenees as well as in the Montagne Noire is represented by 'griotto', rich in goniatites and clymenias. The succession of subsidence and uplifts, transgressions and retreats of the Devonian seas, are nearly the same as in Britanny. With the Upper Famennian the Montagne Noire and Pyrenees appear to have emerged completely. For the Carboniferous sea, coming in during late Tournaisian times, here covers Frasnian, there Middle Famennian, elsewhere uppermost Famennian 'griotto' (the equivalent of the Pilton Beds), thus affording evidence that, between Upper Devonian and Middle Dinantian, continental erosion was at work, or perhaps marine erosion on very extensive continental shelves.

At least it is clear that when the Carboniferous transgression began, the basal sediments were the lydite and phosphate nodule beds referred to on p. 146. I want to emphasise this point particularly.

After Cayeux's thorough investigation of the question of phosphate deposits, the presence of beds of phosphate nodules with their open sea types of Radiolaria, may be regarded as a token that a break, accompanied by very quick changes in sea conditions, took place (Cayeux, L., 1941, p. 14). For instance, a sudden subsidence of the bottom of a continental shelf would produce, as a consequence, violent and far-travelling currents, so accounting not only for the presence of open sea Radiolaria, but also for chemical changes with rapid precipitation of phosphate, lime or silica. His opinion, therefore, was that the phosphate nodules, like a basal conglomerate, afford evidence of sea movements.

If we apply this theoretical view, it gives us the key to an interpretation not only of radiolarian nodules and well preserved plant structures, but also of the general distribution of these lydites with phosphate-nodule beds all through central Europe. They exist at the bottom of Middle and Upper Dinantian beds in Sauerland, east of the Ruhr, and from there through the Harz, Thuringia, southern Czechoslovakia, Upper Silesia, and again in Bosnia.

Through all this same area, there is a big development of limestones in the Lower Devonian. The Middle Devonian is represented by *Tentaculites* shales, while the Upper Devonian displays a remarkable succession of goniatite- and *Clymenia*-bearing beds. All these facts agree with the characters of Devonian and Dinantian formations in the Mediterranean area.

Hence the conclusion is reached that during the Devonian, and later on during the Lower Carboniferous, the Mediterranean Sea extended its transgressional moves northward as far as a large gulf extending over central Germany.

We shall see that the oscillations in Asturias and even in North Africa are in accord with these views.

5. ASTURIAS

The early Devonian seas came from the west and they advanced almost to Oviedo and Gijon (the main port along the coast); the Truvia Valley and the Naranco ridges roughly mark the limit of the transgression of the Coblenzian and Lower Eifelian seas to the east. Ferruginous sandstones, two or even three series of coral and brachiopod limestones, are overlying Gotlandian or Arenigian. An island, corresponding roughly to the high Asturian mountains—the actual Picos de Europa—remained uncovered by this early Devonian transgression, exactly as Ligeria on the southern border of Britanny. Then the sea retreated westward and we do not know the limit of this regression. Certainly Givetian, Frasnian and Famennian are not known east of Gijon. On the northern border of Asturias there is nothing really identified as Famennian. But on the south of the big mountains, on the Province of Leon side, evidence of a short transgression marked by sandstones with *S. verneuili*, has been pointed out by Comte (*in litt.*). It is interesting to note that this is exactly what happened with the Famennian at St. Julien-de-Vouvantes on the southern border of Britanny. Then, also in the same manner as in Britanny and the Montagne Noire, there was a general uplift at the end of the Devonian.

The massif of 'Picos de Europa', and probably a much larger area in north-west Spain, remained continental during most of the Dinantian, so that when the sea came again, late in Dinantian times, Upper Visean 'griottos' were laid directly on Arenigian all over the central and eastern parts of the old massif of the Picos. It is noteworthy that a few tiny phosphate nodules have been found at the very bottom beds of the 'griotto' formation. It is also remarkable that the Visean 'griotto' overlies both the Arenig sandstones, and elsewhere the ferruginous Mid-Devonian sandstones, yet with apparent conformity almost everywhere. Only at Covadonga have I observed a slight unconformity.

The Carboniferous seas remained there until Upper Moscovian times; they opened on the vast Mediterranean area, and received therefrom a pelagic fauna (*Fusulinellae*, goniatites) as well as a neritic, *i.e.*, with spirifers, *Producti*, trilobites, corals (*Chaetetes*).

6. NORTH AFRICA (see Fig. 5, p. 152)

This country may be regarded as being, during the late Palaeozoic, a large semi-circular shield in front of the Hoggar, the Central Sahara crystalline Archean and Pre-Cambrian massifs. This very old continent had been early subjected to tectonic movements, creating, even before the Palaeozoic era, a structure and folding whose main axis runs north to south. These directions reacted as Hercynian tectonics: in the Fezzan, in east Sahara, the Devonian and Carboniferous anticlines are mostly north–south. In the west, the large Saoura Valley runs north-north-west–south-south-east, cutting in two parts the vast continental shelf across which shallow Devonian and Carboniferous seas moved to and fro. Neritic conditions prevailed everywhere except along the Tafilalet, Saoura and Gourara, which were downsunk troughs where deep-sea deposits with goniatites steadily accumulated from Mid-Devonian to Upper Visean and Moscovian.

Central Morocco and north-west Sahara. Exactly as in west Europe, there was a general transgression during the early Devonian (perhaps succeeding the Gotlandian without any break though locally there are graptolite zones missing). A slight regressive movement took place during the late Coblenzian. The Eifelian is represented nearly everywhere by coral limestone while the Givetian is reduced or absent. These are the general lines of the succession. Throughout there was a submarine ridge between the Tindouf and the Taoudeni geosynclines, with Devonian seas advancing or retreating on either side.

The consequence is that, here and there, one of the formations is lacking. The Givetian is very thin or totally absent, as was the case in Britanny. Mistakes can be made when such occurrences are overlooked by geologists in the field, or by palaeontologists working on theoretical views (as is the case with many discussions about the range of *Calceola*).

The most important regression was at the end of the Upper Devonian, when emergence became general. At the beginning of the Tournaisian the Carboniferous sea left the southern border of the Tindouf; in Morocco it covered only a reduced area in the north-west. After that, exactly as all over western and even central Europe, a new transgression began in the Upper Tournaisian, and extended, chiefly during the Lower and Upper Visean, covering the whole Morocco, the Tafilalet and, finally, even the highest part of the Atlas.

Events were similar in the eastern Sahara: Upper Tournaisian and Visean seas cover the whole shield extending from Touat, Tidikelt and Gourara to the Fezzan. However, the extreme limits of these epicontinental seas were not well known until recently. In eastern Libya it seems that the Devonian and Carboniferous do not exist, while to the south-west in Taoudeni and Mauretania, one is not sure that the shore lines were ever shifted further than the Middle Niger Valley. The Saoura depression has been a permanent feature.

Two final questions now arise. What were the connections east and west of these epicontinental seas always moving to and fro, and whence came originally the transgressive waters?

As to the west, let us say frankly that nobody has any certain knowledge. Did the sea occupy only the central part of the Atlantic during the Palaeozoic era? or was the Atlantic Ocean as widely extended to north and south as it is now, as was probably the case with the Pacific Ocean?

But there is more definite evidence available concerning the eastern connections. On that side, the Mesogea was something like the highway through which communications were easy between Europe and North Africa in the west and Central and Eastern Asia as far as Indonesia and Australia on the other side (see Fig. 8).

The geographical distribution of the faunas all along this vast mediterranean sea affords us many interesting facts. Among the Frasnian and Famennian goniatites of the same genera, and indeed of the same species as in Europe or North Africa, have been collected in north-west Australia, with Upper Tournaisian ones in south-east Australia. At the International Geological Congress in London in 1948 the Chinese geologist, Dr. Sun, reported that, after studying for many years the Palaeozoic formations in Yunnan and other provinces of south-west China, his conclusion was that the faunas of the western Mediterranean and of Cathaya were connected and that they had many genera and species in common. Before this, Chao, describing the Carboniferous faunas of central China, had adduced many proofs of such close relationships, as for example the occurrence of *Spirifer mosquensis*, *S. myatchkovensis*, *S. strangwaisi* and others. In the first part of this paper I pointed out that the same *Productus giganteus* and *Daraelites praecursor* exist in Indo-China as in the Pyrenees, and *Productus giganteus* occurs everywhere in Central Asia, Europe and North Africa. Librovitch (1927) has described from Son-Kul in Central Asia a goniatite fauna, somewhere near the limit between Upper Tournaisian and Lower Visean, where species are present that are known also from Tafilalet, from Montagne Noire and Germany, as for example *Munsteroceras subglobosum*, *Pericyclus kochi* and *P. fasciculatus*. *Fusulinella bocki*, *Fusulina cylindrica* lived in Mesogean waters from one end to the other, from north-west Spain to Indo-China. As to the Lower and Middle

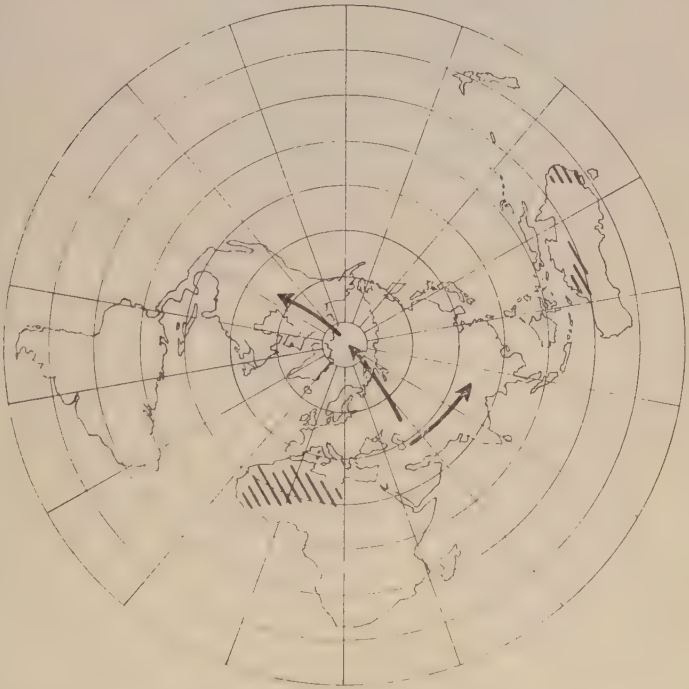

FIG. 8.—Routes of migration of the faunas from western Mesogea through the Urals to the Arctic Region and North America, and from western Europe to the Far East—China, East Indies, Australia. Oblique lines indicate, in North Africa and Australia, the areas from which the same species of Devonian and Carboniferous fossils (brachiopods and corals) have been collected and described. The same should have been drawn over the North Canadian Archipelago and Ohio (U.S.A.).

Devonian of Tafilalet, Miss Le Maître (1947, p. 24) has identified there brachiopods and corals described from north-west India. I have only quoted here evidence from the Far East; similar facts could be produced also from the Near East, as shown by Fr. Frech's studies on the Taurus region (Frech, F., 1916, pp. 210–24); lately R. G. S. Hudson provided us with still more striking resemblances between the Carboniferous brachiopod faunas of north-east Iraq and west Europe (*in litt.*).

There is also another important feature of the Devonian and Carboniferous geography, on which one now has to insist.

I mentioned previously the large gulf that extended from the northern margin of the Mesogea towards central Germany and Bohemia. Further east, in the area now occupied by the Ural Mountains, the Mediterranean Sea itself extended northward, Devonian and Carboniferous marine formations were deposited from the Caucasus to Nova Zemblya. There is a big development of coral or brachiopod limestone in the Lower Devonian, as in Bohemia, in Spain and in Tafilalet. A deep depression with goniatite limestones or shales, similar to that of the Saoura in North Africa, also existed in the Timan region.

There is another remarkable case of relationship between the Urals and Morocco. H. Termier (1933, p. 1199) found in the Famennian beds of central Morocco several species of the brachiopod genus *Halorella*, a genus which persisted in the Alpine area even into the Triassic. This genus is known also in the uppermost Devonian of the Urals, where it has been found and figured by Nalivkin. I mention again the presence of *Stenopronorites uralensis* in the Pyrenees and north of Colomb-Bechar (North Africa), of *Cravenoceras petrenkoi* in Nova Zemblya, a species closely related to *Cravenoceras africanum*; of *Proshumardites karpinskyi* known from North Africa, the Shartymka valley in the southern Urals, and from Central Asia (Delépine, G., 1941, pp. 33–5).

Through the north Urals, the Timan and Nova Zemblya we are reaching the Arctic Region in front of the North Canadian Archipelago and further on, via the American Lakes, Ohio. In a list of Mid-Devonian (Eifelian) corals, described by Miss Le Maître (1944, p. 17; 1947, pp. 24–5), eleven of the species recorded from Morocco are known also in North America, *viz.* seven in Ohio and four in north Canada. Similar observations have been made on Upper Coblenzian brachiopods from south Tafilalet.

These facts may be considered not as a definite proof, but at least as a suggestion that, both during the Carboniferous and the Devonian periods, at least one of the ways of migration of the faunas from North Africa to North America was the eastern Mediterranean and the sea extending from south to north over the Ural region.

One may also say that during the late Palaeozoic, the Mediterranean area seems to have been the centre where many new genera and species appeared first—brachiopods, corals, crustaceans, bryozoans and Foraminifera. This fauna was richer and more diversified than anywhere else, and from this source adjacent sea areas received their new fauna.

7. CONCLUSION

The conclusion will be the answer to the question that has been put forward: was the history of west Europe and North Africa during the late Palaeozoic different from the history of Mesozoic and Cenozoic times, and was the geographical picture between the Caledonian and Hercynian tectonic movements quite different from what the picture was later on, between the Hercynian and Alpine tectonic revolutions?

There was certainly during the Devonian and Carboniferous an archipelago of ridges, tiny islands and partly emerged continents, which were always the same, made of crystalline and metamorphic rocks of Pre-Cambrian or Cambro-Silurian formations—Ardennes, Brabant, Bohemia, the French Central Plateau and Montagne Noire, Armorica, Asturias and Spanish Meseta. On the southern border of the Mesogea lay the Morocco Meseta, part of the Atlas, and a large shield extending more or less north and west of the Central Massif of the Hoggar. One can say that these were the permanent units of our west Continent. Around these, which acted as firm pillars, the sea went to and fro, bringing new material—sand, lime and mud—to fill the inlets and build our actual continent.

In conclusion, one should say that, since the Caledonian tectonic revolution, the contours of our west European and North African continents, taken as a whole, have seen little change; movements of the sea have always been repeated on a smaller or larger scale, with the same rhythm, and in the same areas.

Was it so in earlier times, before the Caledonian main folding phases? That is another question, the key of which is mainly in the British Isles and in Scandinavia. On the Continent as well as here and in Africa, many problems remain still to be studied. May I finally express the hope that these studies may be of value particularly to the younger generation of British geologists and express the wish that they may share in helping to solve the many interesting problems that remain.

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A 400-FOOT BENCH IN SOUTH-EASTERN WARWICKSHIRE[1]

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CONTENTS

	PAGE
1. Appearance and Extent of the Bench	167
2. Provisional Interpretation	168
3. Relative Dating	168
4. Implications and Difficulties of the Interpretation	169
References	172

SUMMARY.—A narrow bench at very nearly 400 feet O.D. has been mapped for thirty-five miles along the edge of the Lower Lias belt in south-eastern Warwickshire. It is provisionally interpreted as a pro-glacial lake-bench cut during the Chalky Boulder Clay glaciation. The grounds for this interpretation are examined and some of the implications considered.

1. APPEARANCE AND EXTENT OF THE BENCH

IN the course of a geomorphological field study, the writer has located and mapped a series of landscape facets in south-eastern Warwickshire. The general form is that of a narrow bench cut into the wall of the Lower Lias vale, and subsequently partly dissected; the inner (rear) edge lies at the base of scarp slopes which descend from the Marlstone or from older resistant beds, while the outer edge follows along the top of shorter, and rather gentler, slopes descending to the vale floor. Because of the dissection, the bench is now represented by flattened spur-tops and narrow ledges, up to a quarter-of-a-mile wide, but there seems little doubt that the several facets are members of a single series: they preserve a constant altitude very close to 400 ft. O.D. from the extremity of the North Cotswolds to a point south of Rugby (Fig. 1) over a distance of some thirty-five miles.

Although the bench is developed chiefly on rocks of the Lower Lias, as a whole it truncates structures. It is unaffected by the faulting of the Dassett Hills or of the Epwell locality, or by dips in the direction of outcrop. Near the lower boundary of the Middle Lias it passes on to some of the highest beds of the Lower Lias, and possibly on to younger strata, while on some outlying eminences facets ascribed to the same series are developed on the Hydraulic Limestones which succeed the Rhaetic.

The bench is well seen near Fenny Compton and north of Priors Hardwick, standing some fifteen to twenty feet above the vale floor.

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It passes into and through the Fenny Compton Gap, in the form of a narrow flat floor, before becoming lost in the faintly undulating country drained to the Cherwell. North-eastwards it has been identified in the uppermost Leam valley, but as yet not beyond. North of Braunston a series of flat-topped spurs at a slightly higher level are thought to be based on resistant rock: it may be noted that at other sites also the 400-ft. bench seems to be discontinued where small structural facets are developed at about the same altitude. South-east of Rugby the undulating topography of glacial drift is not easy to interpret, and, until further work has been done, it is not possible to say whether the bench is, or is not, represented here.

South-westwards from Fenny Compton the bench is observed to round the Dassett Hills, to pass across the mouth of the Avon Dassett Gap, and to continue along the foot of the Edge Hill scarp. Near Middle Tysoe the vale floor itself closely approaches the 400-foot contour, and the bench is represented only by a break of slope at the scarp-foot separated from the vale floor by a rise of some five feet in height. The Stour basin is by contrast well dissected, and the bench stands out well both on the eastern and on the western side of the Vale of Shipston. In the south lacunae are thought to be due in part to the poor definition of forms on glacial drift; it is possible also that woodland conceals undetected facets. Beyond Ilmington the bench is not well developed. Mapping has not been extended to the Cotswold scarp-face, but reconnaissance suggests that corresponding features are not present here.

2. PROVISIONAL INTERPRETATION

Since the bench disregards structures, it must be erosional. In the early stages of mapping it was thought that the bench, together with outlying summits at the same altitude, might be remnants of a former extensive surface developed by the processes of normal erosion, *i.e.*, of a vale floor at a higher level than the present. This hypothesis is not, however, easily sustained in view of the evidence (shortly to be presented) for placing the bench-cutting after the introduction of some of the later glacial drift of this area. If a widespread flat had been developed at so late a stage, one would not expect so great a contrast in depth of dissection as is found in the adjacent Stour and Dene valleys. The facts that the bench does not vary greatly in width, that it is remarkably constant in altitude, that its rear edge is smoothly-curved in plan, and that outlying summits are bevelled off at the same height O.D., appear to the writer to suggest that the features in question are due to wave-erosion along the shore of a pro-glacial lake. On this view, the Fenny Compton Gap would have functioned as a spillway.

3. RELATIVE DATING

Whatever the origin of the bench, it is clearly later in age than both the flinty drift of the Vale of Moreton—Tomlinson's Moreton Drift—and the mixed flinty and Triassic erratic material at several points in the Lower Lias Vale. For example, on Wormleighton Hill bench facets appear to be developed on mixed gravel, while a similar capping on Lady Hill, near Ladbroke, rises to 454 ft. O.D. above spurs planed off at 400 ft. In the Vale of Shipston the bench is thought to have been identified at a lower level than the sill of the Vale of Moreton, which is covered in part by Moreton Drift. If the drift had been introduced after the cutting of the bench, the latter must have been obliterated. Again, on outlying summits, such as that of the Christmas Hill Ridge, flinty drift occurs on the 400-foot flat.

Although the drift succession of the Severn–Avon country has not been fully elucidated, nor finally correlated with the succession of other areas, it can be said that on the views of Tomlinson (1925, 1929 and 1935), Arkell (1943, 1947 and 1947a), Wills (1935, 1937, 1938 and 1948) and Zeuner (1945 and 1946), the drifts cut across by the 400-foot bench are referable for the most part to the Chalky Boulder Clay, or the Antepenultimate Glacial. (The writer is aware of the many difficulties of Pleistocene chronology.) It may be added that at Stretton-on-Fosse one facet at 400 ft. is developed on deposits including oolite gravel referred to the preceding interglacial (Arkell, W. J., 1947, 1947a, and Tomlinson, M. E., 1929). The view is therefore provisionally adopted that the lake was impounded in part by Chalky Boulder Clay ice.

4. IMPLICATIONS AND DIFFICULTIES OF THE INTERPRETATION

Since the fore edge of the bench is very close indeed to the 400-foot contour on the six-inch O.S. map, and since its rear edge rises very seldom above 410 ft. O.D., it would seem that the postulated lake was controlled by outlets competent to carry off any seasonal increment of melt-water. Benching has not been observed at higher levels, nor at lower as far as *ca*. 300 ft. (below which further investigation is required), so that it seems that the 400-ft. level is alone in question. The single spillway located, that of Fenny Compton Gap, does not appear adequate to discharge the whole overflow of such a lake as that envisaged. Other outlets must therefore be sought.

The floor of the Avon Dassett Gap lies above the 400-foot contour, and the bench does not pass through. A flat can be traced into a small re-entrant, at the head of which it ends against the higher ground of the sill. Since the entrance is very narrow, the flat floor of this tiny valley is more likely to be due to silting referred to the lake-level than to wave-erosion.

The Vale of Moreton presents a more difficult problem, but on balance it is considered that no overspill took place here. The sill floor is very close to 430 ft. O.D. at the lowest, so that a barrier of *ca.* 20 ft. above the level of the postulated lake is thought to have existed. Admittedly a low barrier of drift and Lower Lias Clay would be no great obstacle to the attack of powerful waves: at the same time it should be observed that a shoreline recession of about a mile would have been necessary before the barrier were breached. It appears likely, from the reconstructed form of the shore, that considerable recession had already occurred in this locality. In Fig. 2 the topography of the Vale of Shipston, late in the lacustrine stage, is hypothetically reconstructed;[1] it is seen that a bay, deeply penetrating southwards, is studded by shoals and islets and fringed by abrasion-platforms, the latter now represented by slopes descending gradually from *ca.* 400 ft. to as low as *ca.* 325 ft. O.D. If this reconstruction is at all near the truth, it would appear that the southern shore must have been protected in some measure from the full force of waves.

It might be that the sands and gravels which lie generally to the east of Rugby,[2] and contain abundant flinty debris, represent deltaic material built out into the lake directly from the ice-front. If this were so, there may have been at one time a spillway into the Nene Valley, for Thompson (1929) records similar material in the Kilsby Tunnel section extending to well below 400 ft. O.D., *i.e.*, choking the Watford Gap.

If all the foregoing suggestions were substantiated, no more than the south-eastern and eastern shores of the supposed lake would have been defined. Nothing can as yet be said of its remaining boundaries, beyond some brief remarks on the difficulties involved which it is in no way desired to minimise.[3] The leading difficulty is to account for a barrier across the lower Avon. It is not permissible simply to postulate an ice-barrier, since the advances of ice from eastern and western directions during the glacial in question are not thought to have been strictly simultaneous (Tomlinson, M. E., 1935, and Wills, L. J., 1938). Until mapping has been extended along the Cotswold scarp-face nothing can be said further in this respect. To the north, there is no continuous barrier of ground above 400 feet between the Severn–Avon and the Trent basins, so that a lake might have passed across the present divide.[4] Investigation is required into the possibility that a series of features at 400 ft. O.D. may exist on the higher ground south of Birmingham, and it is hoped later to extend field mapping to this area.

[1] This reconstruction may well need to be revised in the light of more recent work.

[2] There are good exposures at Hillmorton and Shawell.

[3] The writer is indebted to Professor S. W. Wooldridge for illuminating discussion on the implications of the views expressed.

[4] Professor F. W. Shotton has kindly discussed the results of his current (and as yet unpublished) work on the Avon Valley and the country to the north. It seems likely that abundant geological evidence will be forthcoming to support the hypothesis of a formerly existing lake. In view of the complete independence of Professor Shotton's and the writer's work, and of the contrasting methods employed, it is gratifying to record that results, in so far as they can be compared, are in agreement. At the same time it must be stated that other interpretations of the 400-foot bench than that advocated here could be adopted without prejudice to Professor Shotton's results.

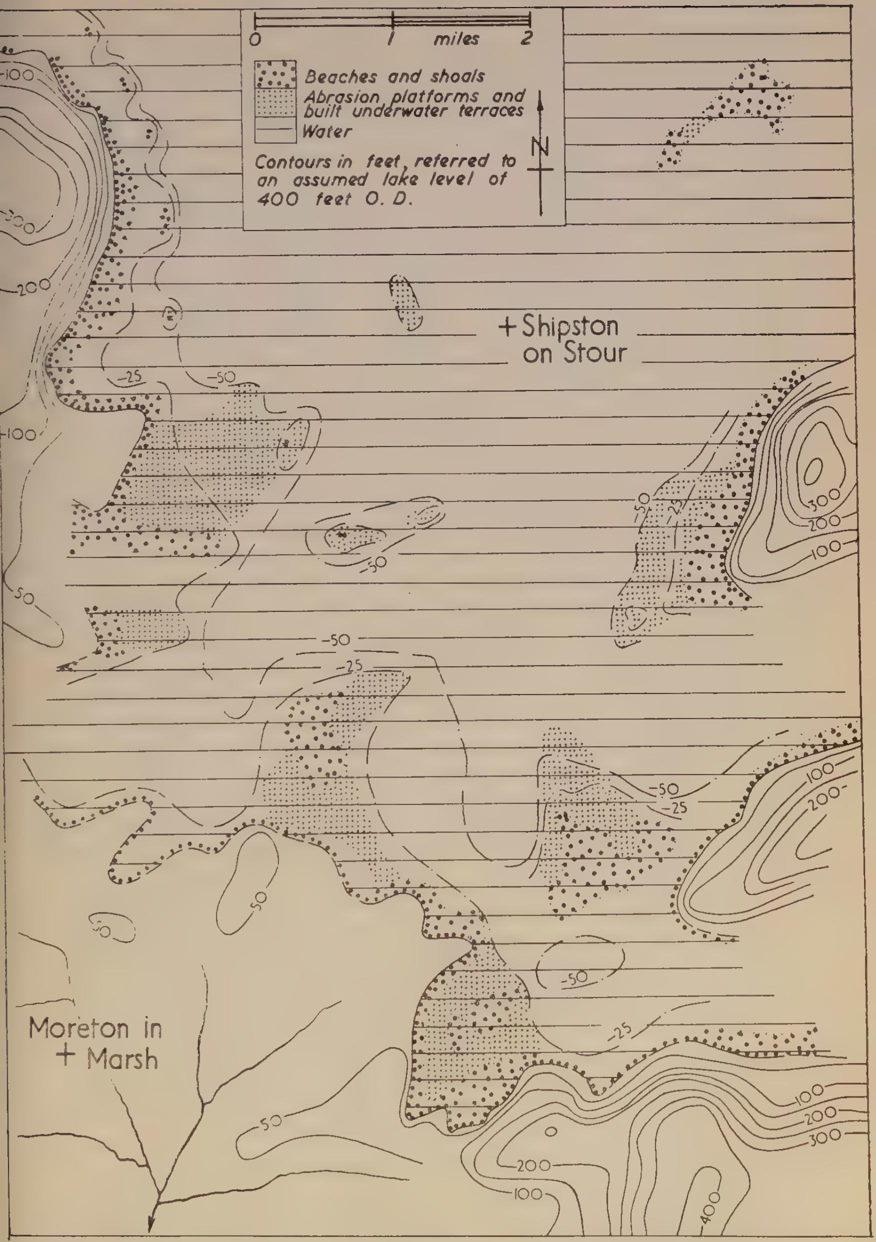
0
1
miles
2
Beaches and shoals
Abrasion platforms and built underwater terraces
Water
Contours in feet, referred to an assumed lake level of 400 feet O. D.
N
+ Shipston on Stour
+ Moreton in Marsh
100
300
200
-25
-50
50
400

FIG. 2.—Hypothetical reconstruction of conditions in the Vale of Shipston at the time of the 400-foot lake.

The inferences to be drawn from the assumption that spillwater flowed down the Cherwell Valley are somewhat more satisfying. Although this valley has been described (Sandford, K. S., 1924), as largely swept clear of terrace material, the overflowing water cannot have been responsible for much of the clearance: for, if the suggested chronological placing is correct, the overspill occurred during the time which separated the Hanborough from the Wolvercote Terraces (Sandford, K. S., 1924, and Arkell, W. J., 1947) hence the highest deposits alone could have been carried away by spillwater. One may note that, in any reasonable reconstruction, the Cherwell profile at the Hanborough stage would pass through the Fenny Compton Gap above the 400-foot level. For what it is worth, this statement may be taken to support the placing of the lacustrine episode after the interglacial in which the Hanborough Terrace was deposited.

In a more general view, it is possible that the interpretation of this 400-foot bench as a wave-cut feature may be objected to on the ground that series of horizontal bench-like features occur elsewhere, in areas where pro-glacial lakes cannot possibly be in question. The cogency of such an argument is fully recognised, and the difficulty is admitted. The grounds for claiming this bench as a series of shoreline features have already been given, but it is worth noting that if in fact it has been developed by normal erosion, there must have been a prolonged stand-still at *ca.* 400 ft. O.D. not earlier than Chalky Boulder Clay Glacial times.

In conclusion, the development of the bench, whether by wave-action or otherwise, may be made to fix relatively on the time-scale certain facts of landscape-evolution in the Lower Lias belt. It is very probable that the scarp into which the bench is cut has, at many points, retreated little since the cutting. It would also appear that the Fenny Compton, Avon Dassett and Evenlode Gaps had all been lowered to little above 400 ft. O.D. before the incoming of the Chalky Drift. Moreover, any dip-streams which formerly headed north of the line of the present scarp had already been reduced by capture, and the floor of the Lower Lias vale had been cut well below the level of the sills. That is to say, the broad pattern of the present drainage and relief was evolved before the Chalky Boulder Clay Glacial.

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DISCUSSION

PROFESSOR F. W. SHOTTON congratulated Dr. Dury on a very interesting and important piece of work. The former had been engaged over the last five years on the mapping of the drifts of East Warwickshire and had come to the conclusion that the nature of these deposits necessitated, during the time of the Great Chalky Boulder Clay, the existence of a great lake more or less in what might be called the Avon Valley, though he hoped to produce evidence that the drainage was then very different from that of the present day. The disposition of the deposits called for a lake level a few feet above the 400-foot contour. It was particularly pleasing to the speaker, therefore, when he learned that Dr. Dury, working on an adjacent area and on quite different lines, postulated a lake bench of exactly the same height. The coincidence was such that it would be a strange thing if the two postulates did not refer to the same lake. The speaker, however, thought it possible that some of Dr. Dury's flats interpreted as erosion benches might prove to be the residuals of the upper surface of the lake deposits, though the answer to that could only be given by the combination of geological mapping with geomorphological observations.

Many glacially-dammed lakes have been delineated in Great Britain, but they are products of late glaciations, and their boundaries are obviously related to modern topography. This Warwickshire lake was different in that it dated from a relatively early glaciation and developed on a topography very different from that of the present-day ; so that any criticism based on the difficulties of impounding the lake should be deferred until that early topography is fully understood.

MISS M. E. TOMLINSON congratulated the author on the interesting results of his geomorphological research in the Midlands. Since the author has recognised parts of the lake-bench developed on flint gravels, she asked whether he could say at what stage of the Eastern Glaciation the lake was impounded. While beach deposits might not be preserved where the bench was cut in the Lias clay, she asked if any such deposits occurred where the bench was cut in the harder marlstones.

A NEW SECTION AT COWCOMBE HILL, NEAR CHALFORD STATION, GLOS., EXPOSING THE JUNCTION OF INFERIOR OOLITE AND FULLER'S EARTH

By P. J. CHANNON, O.B.E.

[*Received 24 August* 1950]

THE object of this note is to record a new section which is likely to be fully exposed for only a short time and may be of importance in the correlation of the strata above the Inferior Oolite in this neighbourhood. The section is the result of a recent widening of the main Stroud–Cirencester road at Cowcombe Hill, Chalford, and was examined at the end of May 1950. It is some 170 yards long with a maximum height of about fifty feet, and is situated just above the railway, on the south side of the main road, 360 yards east of the bridge which carries the road over the railway close to Chalford Station. The National Grid reference for the section is 32/900024. The top (Fuller's Earth) portion of the section, although cut back at a low angle, is already slipping forward badly. Shrubs have been planted over it to assist in retaining the slope, and it will quickly be grass-grown.

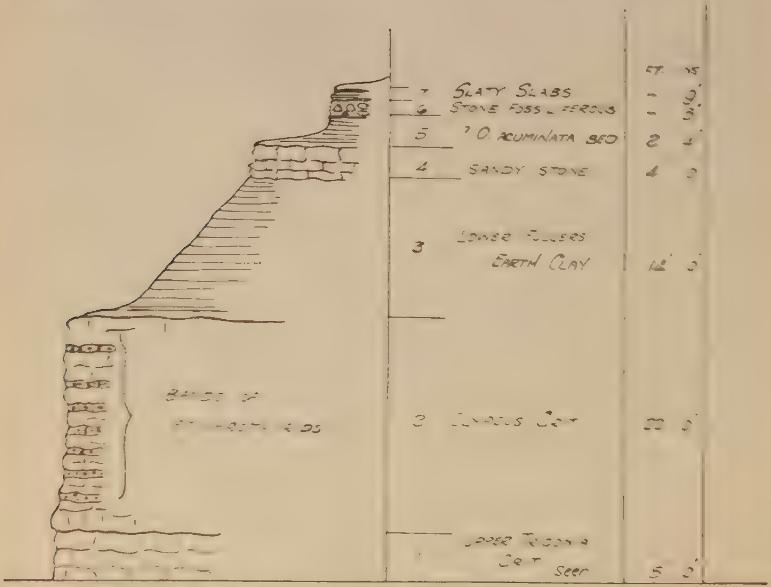
Ft. Ins.
7 Slaty Slabs – 9"
6 Stone fossiliferous – 3"
5 ? O. acuminata bed 2 4"
4 Sandy stone 4 0
3 Lower Fullers Earth Clay 12 0
Seer 5 0

FIG. 1.—Section at Cowcombe Hill, near Chalford Station, Glos.

Fig. 1, roughly to scale, shows the strata exposed, which are as follows:

	ft.	in.
8. Subsoil	1	0
7. Massive slabs, from 4in. to 12in. thick, of very hard, apparently unfossiliferous, evenly fissile, dark, greyish brown, sandy rock similar to the slate beds of the Stonesfield Slate in appearance	0	9
6. Layer of friable, creamy white, decomposing rock packed with *Ostrea (Liostrea) acuminata* J. Sowerby and many other fossils. The rock, from its lithology and contents, appears to be identical with that in the Fuller's Earth below the Stonesfield Slate at Cooper's Hill (Channon, 1950, p. 244) and at Cross Hands, Old Sodbury. *Neridomus anglica* Cox and Arkell, *Anisocardia* cf. *caudata* (Lycett), *Anisocardia rostrata* (J. Sowerby), *Astarte* cf. *depressa* Goldfuss, *Chlamys* (*Radulopecten*) *vagans* (J. de C. Sowerby), *Grammatodon* sp. indet., *Gresslya peregrina* (Phillips), *Isocyprina* cf. *crossi* Cox, *Isocyprina* sp. indet., *Pseudolimea duplicata* (J. de C. Sowerby), *Meleagrinella echinata* (W. Smith), *Pholadomya deltoidea* (J. Sowerby), *Placunopsis socialis* Morris and Lycett, *Pleuromya uniformis* (J. Sowerby), *Wattonithyris parva* Muir-Wood and vars., *Wattonithyris midfordensis* Muir-Wood and vars., *Wattonithyris fullonica* Muir-Wood, *Wattonithyris* spp. (immature), *Kallirhynchia superba* S.S. Buckman	0	8
5. Ostrea acuminata Bed (?). Buff marly clay densely packed with *Ostrea* (*Liostrea*) *acuminata*	2	4
4. Massive sandy brownish stone, rather disturbed; no fossils except a thick layer of *Ostrea* (*Liostrea*) *acuminata* on top surface	4	0
3. Lower Fuller's Earth Clay. Buff and slaty-blue clay with many *Ostrea* (*Liostrea*) *acuminata* and occasional brachiopods, etc. Holding up water	14	0
2. Clypeus Grit. Typical. Coarsely oolitic, brownish-buff limestone, similar to that seen in section at Gilbert's Grave (Richardson, L., and others, 1933, p. 29). Several prominent bands packed with terebratulids in positions indicated in sketch. *Gresslya abducta* (Phillips), *Homomya gibbosa* (J. Sowerby), *Lima* (*Plagiostoma*) sp. indet., *Modiolus gibbosus* (J. Sowerby), *Pholadomya lirata* (J. Sowerby), *Pinna* (*Stegoconcha*) *ampla* (J. Sowerby), *Pleuromya uniformis* (J. Sowerby), *Rhactorhynchia* cf. *hampenensis* (S. S. Buckman), *Stiphrothyris tumida* (T. Davidson), *Stiphrothyris cheltensis* (S. S. Buckman) and vars., *Stiphrothyris birdlipensis* (S. S. Buckman), '*Epithyris*' *permaxillata* (S. S. Buckman), *Serpula* sp., *Clypeus sinuatus* Leske [= *C. ploti* auct.], unusually tall specimen, *Holectypus depressus* Leske	22	0
1. Upper Trigonia Grit. Typical. Hard shelly crystalline limestone, with usual fossils, including *Acanthothyris spinosa* (Schlotheim), *Kallirhynchia acutaplicata* (Brown), *Stiphrothyris* sp., small narrow form. Seen for	5	0
Total depth	49	9

The strata immediately above the cutting were not exposed and have not been examined. The twenty-one feet of Fuller's Earth seen may not, therefore, represent the whole thickness of the formation present in this locality. Near the top of the hill is an old quarry now almost completely filled in with refuse. Its National Grid reference is 32/909020, and all that can now be seen there is some six feet of hard, yellowish, finely oolitic limestone, with few fossils. *Chlamys* (*Radulopecten*) *vagans* was seen with unidentifiable casts of other lamellibranchs. The rock appears similar to that seen in the anti-aircraft trenches that were dug across the top of Minchinhampton Common during the last war, and to the rock at Woodchester Park Farm Quarry which has yielded *Morrisiceras* (Channon, 1950, p. 259).

The author's thanks are due to Dr. W. J. Arkell for bringing the Cowcombe Hill section to his notice, to Professor H. L. Hawkins and Drs. L. R. Cox and H. M. Muir-Wood for determining some of the fossils collected, and to Mr. A. W. Pearce for assistance with the figure.

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* CORRECTED NATIONAL GRID REFERENCES FOR LOCALITIES IN MY PAPER CITED ABOVE

Owing to my absence from England I was unable to attend personally to the correction of the proofs of this paper or to check the National Grid References cited. I am indebted to Mr. P. C. Sylvester-Bradley for pointing out several mistakes in these references, mainly due to citation of the wrong 100-km. square numbers. Corrected references are as follows:

Page 242	Cooper's Hill	32/887142
„ 244	Fiddler's Elbow, Quarry II	32/886142
„ 245	Section behind Cooper's Hill House	32/891148
„ 249	Quarry at Snowshill Hill	42/132323
„ 251, 252	Crane Quarry, Minchinhampton	32/857015
„ 251, 252	Simmonds Quarry, Burleigh	32/862015
„ 253	Slade Quarry, Salperton	42/070215
„ 256, 257	Stanley Wood Quarry	32/803018
„ 257	Marmontsflat Wood Quarry	32/802015
„ 257	Jarvis New Quarry, near Cirencester	31/995999
„ 258	Dagham Downs Quarry	32/999061
„ 259	Woodchester Park Farm Quarry	32/811009

It is greatly regretted that an acknowledgment to Mr. J. Myers, for the excellent photographs of the 'gulls' at Simmonds Quarry, Burleigh, reproduced in Plate 13, was inadvertently omitted. P.J.C.

SOME EOCENE SERPULIDS

By ARTHUR WRIGLEY

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[*Received* 23 *August* 1950]

CONTENTS

	PAGE
1. INTRODUCTION	177
2. SYSTEMATICS	178
3. THE ESSENTIALS OF SERPULID TUBES	193
ACKNOWLEDGMENTS	194
DESCRIPTION OF FIGURES	194
REFERENCES	201

SUMMARY.—A description of the London Clay serpulid *Rotularia bognoriensis* (Mant.), its apical growth, the structure of its tube, its position of life and the origin of its sinistral forms and deformations, with a discussion of its affinities and nomenclature. The English Eocene *Sclerostyla*, their opercula and their living representative. *Turbinia* and other extinct serpulids with completely calcareous opercula. Eocene *Protula* and *Ditrupa* described. The distinctive characters of serpulid tubes investigated.

1. INTRODUCTION

MR. E. M. VENABLES, having made a very extensive collection of *Rotularia bognoriensis* from the London Clay of Bognor, kindly lent me the best of his specimens with the observations he had made upon them, in the hope that I might throw some new light on this familiar species by the aid of his instructive materials. This led me into a general review of the Eocene and Cretaceous serpulids and to a preliminary examination of their living representatives. It was soon evident why the study of fossil serpulids had long been neglected, for, in most cases, their living genera and species are founded upon the characters of the animal or of its chitinous operculum, not upon the very variable calcareous tubes which (with a few exceptions) are all that remain in a fossil state. As a compensation, the corrosive alteration of the shelly substance of fossils preserved in permeable sands and clays reveals structures which have escaped notice in living forms, just as in the case of lamellibranch Mollusca (Wrigley, A., 1946). Nearly all the main types of living serpulids are found in the English Eocene, with some extinct groups, but the following descriptions are limited to species which are the most fully known, reserving many others for a later treatment by the aid of ampler and better material than is now available.

2. SYSTEMATICS

Genus: **ROTULARIA** Defrance, 1827

Rotularia bognoriensis (Mantell)[1]

Figs. 1–15, 20–30

Vermicularia Bognoriensis Mantell, 1822, p. 272.
Vermetus bognoriensis J. de C. Sowerby, 1828, p. 194, pl. 596, figs. 1, 2, 3.
Vermetus bognoriensis J. de C. Sowerby *in* Dixon, 1850, p. 118, pl. 14, fig. 3a.
Vermetus bognoriensis Etheridge *in* Lowry, 1866, pl. 4.

The typical form (Fig. 1), abundantly present in the London Clay at Bognor, is almost discoidal with a shallow concavity on one face and a very depressed, conic spire upon the other. The section of the tube is externally quadrangular (Fig. 29b) with rounded corners, three concave sides and a convex dorsal surface. In nearly all specimens there is a central hole where the apical part of the coil is missing. At maturity, the tube becomes uncoiled and protrudes tangentially, traces of an earlier formation of this feature being marked by a collar on the last whorl (Fig. 1). Occasionally, and in several localities, the free, tangential tube reaches a considerable length, Fig. 2 showing what was thought to be its maximum extension. Recently, however, H. E. Taylor obtained a series of large slabs of Bognor rock crowded with *R. bognoriensis* and upon one of them is the truly remarkable specimen shown in Fig. 3, where the free tube is 3·7 inches long. Another of these slabs (Fig. 4) exposes a tangle of individuals weathered out from the matrix in which they are embedded at various angles. The free tubes here are curved and interlaced in such a way as to show that they grew in the juxtaposition in which they now are seen, for it is inconceivable that they could have been assembled in this manner by a marine current.

Specimens with a higher spire are associated with the discoidal form at Bognor and much more conic forms (Fig. 5) are found in other London Clay localities where discoid specimens also occur, the height of the spire being directly proportionate to the angle assumed by the quadrangular tube-section (*b*) in relation to the axis (*a*) or to the plane (*p*) of coiling shown in Fig. 29. Figs. 1 and 5 show extreme forms, but, in abundant material from many London Clay localities, there are so many intermediaries which have no regular, stratigraphical succession, that they evidently all belong to one species. In many cases the coiled tube shows the irregular alternation of constriction and swelling which is so characteristic a feature of serpulids. In Fig. 29 a comparison is made between *R. bognoriensis*—*b*, and *R. discoideum* (Stoliczka)—*d*, *p* being the plane of coiling, *a* its axis and *u* the upper, or umbilical surface. The difference between the two species is very largely explained by the obliquity of *b* compared with *d*.

The wall of the tube is composed of two distinct layers which can be clearly recognised in hammer-fractured specimens from unweathered Bognor rock, such as that shown in Fig. 6, where the two layers, which appear to be structureless, are only differentiated by their colour, the outer coat being of a lighter tint than the inner. Numerous Bognor specimens, now free from matrix, have lain for long ages in a sandy clay, exposed to a very slow corrosion by circulating water which has revealed some details of structure and dissimilarities of substance. An examination of many specimens is summarised in the diagram of Fig. 7. The inner layer (*i*) remains compact and looks as if it were originally porcellanous. The main mass of the outer layer (*l*) is composed of numerous distinct laminae which have become chalky and friable. This suggests that they were originally aragonite, like the shells of gastropods in the same deposit which are in a similar condition. It is equally and, perhaps, more probable that the calcareous matter of these laminae had a large admixture of animal matter. The external skin (*s*) of the outer coat is brownish and has all the appearance of calcite as it is found in other organisms of the deposit (*e.g.*, *Ostrea* and *Pecten*) which are known to be calcitic. Fig. 22 shows this calcitic outer skin (dotted) worn away in places to expose the white laminae beneath. Some concretionary slabs, found in the London Clay at Bracknell, are crowded with *R. bognoriensis* mixed with *Aporrhais* and other gastropod Mollusca. There is a striking difference between the two groups; *R. bognoriensis*, protected by its brown skin of calcite, is entire and uncorroded, while adjacent shells of aragonitic Gastropoda have almost disappeared, leaving only a chalky film over an internal cast of matrix. Fig. 8 shows an accidental cross-section from the London Clay of New Malden: only the inner layer and the outer skin remain, the laminae having entirely disappeared, leaving an annular cavity. This, with the foregoing description, may suggest that the tube wall of this species has really three layers, but the clear indication of two layers in Fig. 6 is supported by the sections of allied species, *e.g.*, by those of *Rotularia spirulaea* (Lam.) from the Eocene of Kressenburg (Bavaria) and by the two-layer structure which is universal in the serpulids, to which we shall find that this species belongs. The calcitic element in serpulids is well demonstrated at Kressenberg, where calcitic *Ostrea*, *Spondylus* and the serpulids are unaltered, although all the aragonitic Mollusca are reduced to mere moulds and casts. The bore of the tube in *R. bognoriensis* is usually more or less excentric, being nearer to the centre of the coiling than to its periphery; in other words, the outer layer of the tube wall is thicker on the outside of the coil than on its inside. This is much more apparent in keeled species like *R. spirulaea*.

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[1] The familiar specific name is left unamended although it implies a 'Bognoria'.

A few specimens of *R. bognoriensis*, like the Highgate example shown in Fig. 9, show a superficial pattern of minute wrinkling and a very similar pattern is found upon the surface of the related *R. leptostoma* (Gabb) from the Claiborne Eocene of Brazos River, Texas. Thinking that this might be a secondary mineralisation analogous to the patterning of beekite, I submitted specimens to Dr. W. Campbell Smith who considers that the pattern is part of the organic structure of the shell, perhaps revealed by some special sort of weathering.

Fig. 10 shows *R. bognoriensis* from the London Clay of Worcester Park, attached by its apex to a fragment of the free tube of a larger individual: this shows that, in the position of life, the concave or umbilicated face of the shell, with the aperture, was uppermost and the apex below. Seen in this position, the coiling is clockwise, or dextral,[1] and the shell is the exact opposite of the molluscan *Solarium* which has a similar form, but which coils to the left when viewed on the umbilical face. The molluscan analogue is the involute *Planorbis*. In what follows we shall see that this species originates in a growth upon a solid object and in such a case, when a spiral coil develops, its apex must be below and, if the coil becomes conic and umbilicated, then the umbilicus *must* be above. This conclusion, being geometrical, is independent of observation, but similar specimens, establishing the position of life, like that shown in Fig. 10, are known in several related species, as in *R. leptostoma* (Gabb) from the Texan Eocene and in *R. spirulaea* (Lam.), from the Cuisian of Bos d'Arros, near Pau. Although *R. bognoriensis* is found in growth-attachment to whole or fragmentary examples of its own species, its adult forms are never attached to molluscan shells or to similar foreign objects of comparable size.

By a happy chance, in the Bognor specimen shown in Fig. 11, the initial apical growth is preserved upon a mature individual. It consists of an almost straight tube which bends sharply before joining the early coils which, as usual, are missing. Mr. Venables has found some very fragile specimens in the London Clay (Bognor Rock horizon) of Aldwick Street, Bognor. Among them are an apical tube, the first coil adhering to an *Anomia* (Fig. 12) and early coils without a closed apex (Fig. 13). Similar material was collected by Mr. A. G. Davis in the London Clay at Warden Point, Sheppey. In all these specimens little more remains than a decayed calcareous film over the matrix which fills the bore of the tube. Evidently, at this early stage, the shell wall was very thin and was composed of aragonite or had so large an admixture of animal matter that it had little resistance to corrosion and its disappearance accounts for the hole in the centre of most specimens. Fig. 14 shows that the central hole is not an effect of fossilisation but had already appeared in dead shells lying upon the London Clay sea-bed, for here is a specimen in which a meandering apical tube has grown right through the central hole of its host, while another, on the left, is bent double inside it. The apical tube has been noted in some related species, in *R. spirulaea* (Lam.), in *Rotularia* sp. of the Claiborne Eocene of Texas[1] and in two American Eocene species in the figures of Gardner (1939, pl. 6, figs. 2 and 19). Another specimen (Fig. 15) from Aldwick Street, Bognor, shows centrally a cross-section of a knot or contortion in the apical tube just before it became regularly coiled: this is frequently found in *R. spirulaea* and is illustrated for that species by Fig. 16, the unbroken contortion being shown in Fig. 17. This apical growth resembles that of the living *Spirorbis borealis* (Linn.) which differs from the extinct *Rotularia* by its far smaller size and by being totally adherent, by one flat face, for its entire growth. Fig. 18 (after Fewkes) shows, on the left, the free, larval tube (*t*) of *S. borealis*, *o* being the operculum and *c* the collar of the animal, while on the right the tube is shown bending sharply, just before the coiling which originates with its fixation. Fig. 19, from a specimen detached from seaweed at Bembridge, shows the origin of the coil from which the delicate larval tube has vanished.

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[1] I am unable to follow the reasoning of those students of living serpulids who maintain that the well-known *Spirorbis borealis* (Linn.) found so plentifully on the bladder wrack of our coasts, is sinistrally coiled, although the face which can be seen in the adherent position of life, coils clockwise.

Having noticed that a few of his specimens of *R. bognoriensis* were sinistral, Mr. Venables counted a very large random assemblage and found that 95 per cent were dextrally and 5 per cent sinistrally coiled when viewed with the apex below. Mr. H. E. Taylor verified this result by counting several hundreds of his own collection. The origin of these sinistral forms is seen in a specimen from Aldwick Street, Bognor, shown in Fig. 20. An apical tube began to grow on the lower, convex side of a mature individual, near the periphery and, as if the creature realised that this was the wrong place for its development, its tube became contorted, then crossed the rim and started to form its mature coil on the upper, concave surface of its host. In this reversed plane of existence, its coiling is sinistral and exactly the same may be observed in other rare examples which are known, such as the recent find illustrated in Fig. 21, which admirably demonstrates the central hole, the meandering apical tube (*a*) and the mode of production of a sinistral individual near the aperture of a dextral host. In a few cases, where two mature specimens are associated, as if one had grown upon the other, as in Fig. 22, one is dextral and the other sinistral. It will be seen that the very high proportion (5 per cent) of sinistral individuals must have originated by the accidents of larval fixation. The contorted apical growth shown in Fig. 20, like the normal apical tube, is very friable and seems devoid of the calcitic skin of the mature coils, so that in most cases it has disappeared. In Fig. 23 we see a resumption of coiling and a second tangential growth after the first formation of a free tube. Fig. 24 represents a case of injury where the tube has been irregularly re-formed. At the origin of the secondary growth, the shell wall is imperfect, as if by haste, and lacks its calcitic skin, so that corrosion and attrition have formed a hole or pseudoorifice. Another injury is shown in Fig. 25, perhaps from a fish bite, for a piece of the tube has been removed, well to the rear of the aperture, and the coil is there rejuvenated by a new tube which has overridden the remains of the old one, with an odd appearance of two apertures. These considerations will explain the chapter of accidents seen in Fig. 26 where we may trace loops over adhering tubes of other individuals crossing the rim and seen in cross-section and several distortions by rejuvenation after injury. Fig. 27 shows an abnormal association of two individuals so closely coiled together that they appear to form a single specimen with two apertures.

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[1] H. B. Stenzel has most kindly provided me with a series of *Rotularia* from Brazos River, Texas, carefully chosen to display the apical growth and mode of attachment, etc. They fully agree with those of *R. bognoriensis*.

Fig. 28 shows a free tube, from the London Clay of Whitton (Middlesex), broken away from one of the coiled *R. bognoriensis* which are common at that locality. It has the quadrangular section characteristic of the species but it has the unique peculiarity, at the distal end, of numerous perforations which penetrate into the outer layer without reaching the interior. These holes are oval at the surface as if they run obliquely and they have raised rims. Similar perforations observed in another genus, are noted on p. 188.

The various modes of coiling, from almost discoid to conic, may have depended on the rate of accumulation of London Clay sediment. Where this was rapid, the creature had to raise its tube in a conical form to keep its aperture in water, clear of silt. With slower accumulation, discoid forms might prevail. This remark applies to *R. bognoriensis* occurring in most London Clay localities as individuals isolated in the clay, even when they are abundant. The agglomerations found in the Bognor Rock require further consideration. Mr. H. E. Taylor has obtained there a stony mass 4ft. 7½in. long x 12in. x 3in. thick, almost entirely composed of these organisms which, in another bulky specimen, from which Fig. 3 is taken, give clear indications of being in the position of life. At what is now Bognor the creatures must have pullulated in heaps upon the sea bed, the living growing upon or among their dead predecessors. In many cases, the free tubes in these Bognor masses have their ends bent downward relatively to the inferior apex, as if the creature needed to bring its aperture nearer to the sea bed.

Stoliczka, Cossmann and other authors have placed this organism in the Vermetidae, among the gastropod Mollusca, but the preceding descriptions show this to be an error. All the Vermetidae, like other gastropods, have a closed, spirally coiled apex, while *R. bognoriensis*, like *Spirorbis*, originates in a straight, open-ended tube which is attached to a solid object. As already noted, a gastropod of similar form, like *Solarium*, has an exactly opposite mode of coiling and is not attached at its apex. Then, too, *R. bognoriensis* has a tube wall whose structure is that of a serpulid, with an outer skin of calcite, where the shell of a vermetid or any comparable mollusc, is aragonitic. Although it belongs to an extinct group, we may infer that *R. bognoriensis* was a serpulid annelid.

If this species had an operculum, it must have been entirely of organic substance, because no remains of it have been found fossilised.

Distribution. *R. bognoriensis* is generally, but sporadically, distributed in the middle and upper parts of the London Clay in both the London and the Hampshire basins, being abundant at Bognor, Bracknell, Wokingham and Highgate. It is absent from the Basement-beds and also from the lower part of the London Clay, excepting at Clarendon and Alum Bay.

R. bognoriensis is recorded in the Sables Ypresiens of several localities near Brussels and I have verified this by specimens lent by the Institut Royal des Sciences Naturelles de Belgique through Dr. Glibert. Although hitherto unrecorded there, it occurs in a comparable, perhaps contemporaneous deposit in the Paris basin—the Herouval horizon at the top of the Sables de Cuise, near Gisors. Specimens of my own collecting led to inquiries among French friends, and L. Feuguer and J. Morellet have sent specimens from the niveau d'Herouval at Mt. de Magny and at Liancourt St. Pierre. One of them is illustrated in Fig. 30 which shows an apical attachment to a fragment of *Dentalium.* The Liancourt occurrence appears, by a double error, as *Serpula spirulaea* Lam., in Cossmann, 1912, p. 141, where, in the annelid genus *Burtinella,* it is included in the gastropod Mollusca. These Belgian and French specimens, which are associated with *Nummulites planulatus*, all reach the maturity indicated by the tangential tube at a diameter of 8–10 mm., while in the London Clay the comparable diameter is about 20 mm. In other words, the Cuisian specimens are mature at half the size of those of the older London Clay, but all being otherwise identical this is scarcely a reason for assuming an evolution and creating a new species to enregister it.

Comparisons. *R. bognoriensis* belongs to a large generic group of extinct serpulids which are all spirally coiled, with a protruding free tube at maturity, when specimens are perfect. Under the generic names *Serpula*, *Vermicularia*, *Rotularia*, *Spirulaea*, *Burtinella* and *Tubulostium* they have been described from Cretaceous to Lower Oligocene deposits, ranging from Mexico and the Southern United States, through Europe to India. Among the best known species are: *Tubulostium discoideum* Stoliczka in the Cenomanian Utatur group of S. India (Fig. 31); *Vermicularia concava* J. Sby. in the English Gault and Upper Greensand; *Tubulostium leptostoma* (Gabb) and some other Eocene species from the Gulf States of America which are well figured by Gardner[1]; '*Solarium*' *nysti* Galeotti, a sinistral species[2] of the Sables de Wemmel; *Serpula spirulaea* Lam. (Fig. 32) well known in the Lower and Middle Eocene from Biarritz to Bavaria; and '*Vermetus*' *nummulus* von Koenen from the Lower Oligocene of Lattorf, which is the latest horizon in which the genus has been found.

The generic name appropriate for the group to which *bognoriensis* belongs requires discussion. The Linnean *Serpula* may wisely be retained for a great many fossil annelids of dubious affinities, but here is a group of at least thirty extinct species of a well-defined form which surely deserves a generic name. *Vermicularia* Lamarck, 1799, is inapplicable because it is based on a single living species—*Serpula lumbricalis* Linn.—which is a vermetid mollusc. The earliest available name is *Rotularia* Defrance, 1827, whose type is *Serpula spirulaea* Lam. (Fig. 32). *Spirulaea* Bronn, 1827, *non* Péron and Leseuer, 1807, is based upon *Serpulites nummularius* Schlotheim, a 'species' which includes *spirulaea* Lam., *bognoriensis* Mant., an indeterminate annelid and some Foraminifera. Later, in his *Index Palaeontologicus*, Bronn recognised that *nummularius*=*spirulaea*, which agrees with Schlotheims' type locality of Verona. *Burtinella* Mörch, 1861 (=*Moerchia* Mayer, 1860, *non* A. Adams) includes forms like *bognoriensis* but also some highly conic and pupiform species, so that Cossmann's selection of one of the latter ('*Vermetus*' *turbinatus* Phil.) as the type, is a convenient interpretation. *Tubulostium* Stoliczka, 1867, type *T. discoideum* Stol. (Fig. 31), although interpreted by its author as a Cretaceous mollusc, is a spirally coiled, discoidal serpulid which is closely congeneric with *bognoriensis*. Mörch, Cossmann and Rovereto all refer to a *Rotularia* Lamouroux, 1822, as antedating Defrance's proposal of that name, but prolonged search and inquiry fail to disclose this genus of Lamouroux which is not in the exhaustive indices of Sherborn or of Neave. The conclusion here adopted is to use *Rotularia* Defrance with the proviso that if it is found to be preoccupied, then *Tubulostium* Stoliczka must replace it.

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[1] In these illustrations the sections and profiles show the organism upside down with its inferior apex uppermost.

[2] The living *Spirorbis* includes both dextral species and sinistral species.

The remarkable length of the free tube of *R. bognoriensis* shown in Fig. 3 may be thought to be a suitable criterium of a new genus, but it is not unique among the group of extinct, coiled serpulids to which it belongs, all of which have a free tube of greater or less extent. Fig. 32 shows an aspect of *R. spirulaea* not generally known by previous illustration, and, among the Cretaceous serpulids, *R. ampullacea* (J. de C. Sby.) has a fairly long tube free from the central coil. To create a new genus here, for the peculiarities of *bognoriensis*, would follow the regrettable tendency to give generic value to clear and unequivocal specific characters, leaving species to be defined by insignificant distinctions.

Genus: **SCLEROSTYLA** Mørch, 1863

Sclerostyla Mørch (1863, p. 386), proposed as a subgenus of *Serpula* Linn., was defined by its *operculum et petiolus calcarea* and included three species—*S. ctenactis* Mørch, living in the Antilles, the fossil *S. trochoides* Nyst (which greatly resembles *S. mellevillei*) and the fossil *S. crassa* J. Sby. One, probably both, of the two fossils (which are discussed below) have completely calcified opercula in sharp distinction from the great majority of living serpulids whose opercula are chitinous, with included calcified discs in some genera and species. Being unable to obtain *S. ctenactis* from any European Museum, I was glad to be able to borrow a specimen of it from the Allan Hancock Foundation in the University of S. California, by the kindness of Dr. Olga Hartman, who has sent notes of its distribution. This specimen (Fig. 38) was of the animal in spirit without its tube.[1] The operculum is completely calcified, with a brown, chitinous integument and is plainly of the same type as that described for *S. mellevillei*, with the stalk grooves branching on the cone into a network of reticulations. In *S. ctenactis* the disc is covered by the chitinous envelope which here is studded with slender spines or hairs, while the rim of the cone has a ring of chitinous tubercules. In fossilisation, any such chitinous envelopment would have disappeared. *S. ctenactis* is a shallow-water, marine species, found in the W. Indies at St. Thomas, St. Croix, Barbados, Panama, Colon, and at Octavia Bay, Colombia, which is the locality for Fig. 38.

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[1] This is a not infrequent state of affairs in spirit collections of living serpulids whose collectors have thought that the tube had no diagnostic value.

Leaving aside *S. crassa* whose characters, as will be seen below, are not fully known, the living *S. ctenactis* (Fig. 38) and the Lower Oligocene fossil *S. trochoides* (Figs. 46 and 47) have opercula of a similar type, so that *Sclerostyla* Mørch should be considered as a distinct genus characterised by the completely calcified operculum in which the stalk has two incised grooves which branch repeatedly upon the cone into a network of incised reticulations.

Sclerostyla mellevillei (Nyst and le Hon)

Figs. 33–7

Dentalium elephantinum Solander *in* Brander, 1766, p. 11, fig. 11, *non* Linné.
Serpula heptagona J. de C. Sowerby, 1844, p. 51, pl. 634, figs. 7, *non* Hagenow, 1840. (*Serpula heptagona* of Ethelred Benett, 1831 and of Münster, 1835, are *nom. nud.*)
Serpula mellevillei Nyst and le Hon, 1862, p. 1.
Serpula heptagona Etheridge *in* Lowry, 1866, pl. 2.

J. de C. Sowerby, with his excellent figures of this Barton species, used an obviously descriptive specific name which, as so often is the case, is preoccupied, so we must adopt the later *mellevillei* proposed by Nyst and le Hon for the same species found in the coeval Sables de Wemmel near Brussels.

The tube (Fig. 33), with a generally rough and irregular aspect, has seven flanges which are sharp in the early growth, but become rounded, to a variable degree, towards maturity. Transverse lines of growth are sinuous in proportion to the saliency of the flanges; when this is small they are almost straight. In its early stage the tube is attached to some solid object—at Barton usually to a *Dentalium* (Sowerby's figures) or to a *Ditrupa* (Fig. 34)—the number of the flanges increasing from three to seven as it becomes detached from its support. Young individuals broken away from their base, show a cellular structure on the adherent surface (Fig. 35) which is very characteristic of all attached serpulids.[1] In juveniles the flanges are very salient and a pair of them may project like wings. One Barton specimen has been noted in which a juvenile has commenced growth by fixation near the aperture of a mature tube and, in Fig. 36, we see three individuals conjoined at first but soon separating and diverging to their mature growth as free, straight and upright tubes. The upright habit may be inferred from Fig. 35 where the tube is seen to bend sharply upward from a horizontal fixation. The tube-wall plainly consists of two layers, the inner one of uniform thickness, the outer often much thicker on one side than on the other, so that the bore is excentric (Fig. 36).

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[1] Triangular or circular tubes of species which adhere for their full length, are cellular at each side of the attachment, while the tube immediately below the bore is incomplete and reduced to a mere film with stouter bridges at intervals, so that the trace left upon the support resembles a ladder. This also can be seen in the living *Spirorbis* (Fig. 19*b*).

The completely calcareous operculum (Fig. 37) is most commonly found separately, but is sometimes embedded in the aperture of the tube to which it belonged (Fig. 33), leaving no doubt of the association. No other type of operculum has been found at Barton.[1] This operculum may be considered as a *stalk* expanding into a *cone* whose upper surface is a *disc* (Fig. 37). The stalk is composed of numerous calcareous rods, seen at the tip when it is corroded, and is bifid by two opposite, incised grooves. On reaching the cone these grooves branch repeatedly into a network of incised reticulations. The concave disc bears major and minor rays which sometimes appear as chains of tubercules. The angle of the cone varies and the stalk is always more or less excentric to the disc. Accidental breakages of the cone disclose a spathic fracture, like that seen in the radioles and tests of fossil sea-urchins. The external sculpture of this operculum suggests that it is entirely composed of rod-like elements which branch and diverge repeatedly in the cone and end on the disc in the tubercules of the rays, the ends of their lower branches being seen on the cone between the incised branchings (Fig. 37, magnified detail). The rods of the stalk and the reticulated cone are seen in the operculum of the Upper Cretaceous *Hamulus onyx* Morton (Wade, B., p. 30, pl. 2, figs. 4–6) which has the stalk triangular by three salient flanges.

Distribution. In the Barton beds of Barton at horizons A3 (rare tubes); E (tubes and opercula frequent); H (very small opercula, rare). Auversian Upper Bracklesham beds at Selsey (a few tubes but no opercula). Sables de Wemmel near Brussels (tubes and opercula common). Lutetian Bracklesham bed at Selsey (rare tubes), and at Southampton Dock (rare opercula). At the last locality there are also opercula with the reticulated cone of a much smaller angle than in the Barton form and like those which are characteristic of the basal Calcaire Grossier of the Paris Basin (Wrigley, A., 1950a, p. 503, fig. 4). At Southampton this type of operculum *may* belong to tubes whose prolonged adherence to *Turritella* is triangular, becoming heptagonal when the upright, free state develops. The question whether this Lutetian form is a separate species must await the discovery of better specimens, with the operculum related to tubes which differ from those of the Barton *Sclerostyla mellevillei*.

Sclerostyla opercula are found in west Europe in Ypresian, Cuisian, Lutetian, Bartonian and Lattorfian deposits. Now, that any single species should be found almost continuously from the London Clay to the Lower Oligocene is exceedingly improbable in view of what we know about the complete changes of innumerable marine species of west Europe during this great tract of time. The opercula, despite variations in the angle of the cone, give no firm grounds of specific distinction, for which we must look elsewhere. Here is a difficulty, for the only other remains available in a fossil state are tubes, which, in most living serpulids, are found to be so variable as to be valueless for a complete specific diagnosis. For this reason, the following species, distinguished by peculiarities of their tubes, are proposed with some hesitation, to avoid the great improbability of a single species, based upon an identity of opercular characters, ranging from the London Clay to Recent times.

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[1] Collectors at Barton have christened these objects 'tin-tacks'.

Sclerostyla gallica n. sp.

Figs. 39–40

Serpula heptagona W. Schmitt, 1927, p. 142, pl. 10, figs. 1–5 and 10 *non* Hagenow, 1844. [Hagenow's species is from the Maestrichtian Chalk of Rügen.]

Holotype—tube, Sables de Cuise, Barisis au Bois (Aisne), Fig. 39*a*.

Paratypes—tube, Fig. 39*b*; opercula, Fig. 39*d*, *e* from the same locality. All in the collection of J. Morellet, Paris (ex G. F. Dollfus).

The seven well-rounded ridges of the tube are divided into close tubercules: the tube wall is plainly composed of two distinct layers (Fig. 39*b*). Near the aperture of a mature tube (Fig. 39*a*) a slight corrosion reveals closely packed pores which seem to be the ends of minute tubules forming the outer layer. Specimens occur conjoined at their origin (Fig. 39*c*). The associated opercula (Fig. 39*d*, *e*) have all the characters described for *S. mellevillei*, the angle of the cone being variable. A unique, heptagonal serpulid tube from the top of the London Clay at Rayleigh (Essex) has the same characters of tuberculated ridges and a porous structure of the outer layer. Where the original surface is preserved (Fig. 40*a*), it is studded with minute, close rings which are the closed, domed ends of tubules like those shown in Fig. 39*a*. In other places (Fig. 40*b*) where the surface is corroded, it is covered with annular cross-sections of these tubules which are elongated on the ridges where, evidently, they run obliquely. Faint traces of cross partitions are seen in the elongated rings. This remarkable structure[1] is really part of the tube wall and is not the remains of some encrusting organism like a Polyzoan. The Rayleigh specimen has sinuous rolls below the aperture like oxhorns which are present in many other fossil serpulids. The specific characters of tubercular ridges and a microporous structure of the outer layer have not been seen in *S. mellevillei*.

Sclerostyla perforata n. sp.

Figs. 41–5

Serpula heptagona Sow. [from the London Clay at Wokingham]: Wrigley, A., 1925, p. 453.

Holotype—tube, Fig. 41, London Clay (Modiola Bed) Wokingham.

Paratype—operculum, Fig. 44, from the same locality.

The free tube (Fig. 41) between its seven acute flanges, has irregularly scattered perforations which cannot be the work of any parasitic borer because all have a raised and rounded rim. Accidental transverse sections show that these lipped holes are the ends of tapering tubes in the outer layer which do not penetrate to the inner one. They run almost longitudinally at their small ends, bending sharply as they approach the outer surface, in this respect following the same lines as the laminae of the outer layer described in the next species (Fig. 46*b*); some associated fragments of tubes lack these holes which seem to occur solely towards the mature aperture. The perforations strikingly resemble those of the unique free tube of *R. bognoriensis* shown in Fig. 28. Specimens from the London Clay (Modiola Bed), of Bracknell show this species as gregarious, with the tubes attached to one another for much of their length and united by the cellular structure (*ca*) previously described (Fig. 42, where much of the tube wall is removed by breakage and where part of the matrix filling the bore, appears as a slightly tapering cylinder *c*.) The operculum (Fig. 44) which is found *in situ* in its tube (Fig. 43) has all the characters described for that of *S. mellevillei*. Sometimes its concave disc leaves a cast in the matrix, with an illusory appearance of a convex disc. In one operculum from Wokingham (Fig. 45) the reticulations of the cone fade upward into regular continuations of the disc-rays, in this respect approaching a type of operculum noted below as confined to the Auversian Eocene.

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[1] See Nicholson, H. A., and R. Lyddeker (1889, pp. 472–3) for vesicular structures in serpulids.

Distribution. *S. perforata* occurs in the Modiola Bed of the upper London Clay at Bracknell and at Wokingham (Berks.) where it is common, often in masses in septaria. Some tubes with opercula *in situ* from the middle London Clay of Lower Swanwick (Hants.) probably belong to this species although their perforations are not observable, for they are decorticated and wedged into a crevice in a mass of *Ostrea* and *Pinna*.

Sclerostyla trochoides (Nyst)

Figs. 46–7

Cyclolites trochoides Nyst, 1843, p. 634, pl. 15, fig. 12.[1]
? *Turbinia infundibulum* Roemer, 1863, p. 226, pl. 37, fig. 1a.[2]
Serpula (*Sclerostyla*) *mellevillei* var. *trochoides* Rovereto, 1904, pp. 24–5.

Figs. 46 and 47 illustrate specimens from the Lattorfian sands of Neerepen and Grimmertingen (north Belgium) kindly lent through Dr. Glibert by the Institut Royal des Sciences Naturelles de Belgique. The faintly heptagonal tubes (Fig. 46*a*) have lost their thin external skin by an attrition which has exposed the laminations of the outer layer. In Fig. 46*b* these laminae are seen to consist of closely packed elements like very broad funnels with projecting rims which form the

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[1] Where a serpulid operculum is described as a new species of coral from the Lattorfian Lower Oligocene of north Belgium.

[2] A serpulid operculum described as a new Polyzoan from the Lower Oligocene of Lattorf. From the figure it may well be *S. trochoides* (Nyst), for it is of the same age, but I have not been able to get a Lattorf specimen for verification.

No. 535

GEOLOGISTS' ASSOCIATION · LONDON ·

SESSION 1950-51

President
T. EASTWOOD, A.R.C.S., M.I.M.M., F.G.S.

SPECIAL GENERAL MEETING
followed by a Lecture

A SPECIAL GENERAL MEETING of the Association, convened by the Council in accordance with Rule XXII, will be held at the **Apartments of the Geological Society of London,** *Burlington House, Piccadilly, W.*1, *by kind permission of the Council of the Society, at* **6 p.m.** *on* **Friday, 5 October 1951,** *for the purpose of*

(1) Proposing the following Resolution:

> "That on and after 1 January 1952, the subscription be increased to One pound per annum";

and (2), if this Resolution be adopted, of proposing the following modification to the Rules:

Rule VIII. Amend to read as follows:

> In the second line, for the words "Ten Shillings" substitute the words "One Pound."

The amended Rule will then read as follows:

"Ordinary Members shall pay an Admission Fee of Ten Shillings, and an Annual Subscription of One Pound, and shall not be entitled to any of the rights and privileges of Membership until the Admission Fee and the first Annual Subscription shall have been paid."

LECTURE

Immediately following the Special General Meeting, a lecture entitled "SOME NOTES ON THE GEOLOGICAL STRUCTURE OF THE ENGLISH MIDLANDS" will be given by G. H. MITCHELL, D.Sc., Ph.D., F.G.S.

The lecture will be illustrated by lantern slides.

Visitors may be introduced for the lecture only.

[*Continued overleaf*

ANNUAL REUNION

The Annual Reunion will be held on Saturday, 3 November, 1951 at the Chelsea Polytechnic, Manresa Road, S.W.7, by kind permission of the Principal. Members who propose to exhibit are requested to send a note of the title of the exhibit and particulars of accommodation required to the Secretary **not later than 3 October.**

LIST OF MEMBERS

A new List of Members is being prepared and members are asked to notify the General Secretary, as soon as possible, of any changes in address, etc., not previously advised.

PROCEEDINGS

Part III for 1951 is issued with this Circular to those members whose subscriptions are not in arrear.

Geological Survey and Museum,
Exhibition Road,
South Kensington, S.W.7.

R. REELEY, F.G.S.,
Secretary,
21 September 1951.

close, transverse annular lines. The transverse section (Fig. 46*c*) shows a bore which is excentric because some of the outer laminae do not completely encircle the inner. The associated opercula (Fig. 47), clearly resemble those of *S. mellevillei.*

The rimmed laminae are analagous to the 'parabolic layers' described by Götz (1931 p. 391) in the outer layer of the tube of the Upper Cretaceous *Serpula heptagona* Hagenow which seems to belong to *Hamulus*, in which a similar structure has been described by Stephenson (1923, p. 71). These parabolic layers have their rims pointing inwards so that they determine a constriction of the aperture like that of *Ditrupa*. A Judean Cretaceous species, described as *Hamulus* by Avnimelech (1941, pp. 3–6), has laminae[1] with the rims pointing outward, like those of *S. trochoides* and determining a projecting rounded rim or collar at the aperture, whose presence in other species may suggest this type of lamination. Götz (*op. cit.*) describes and figures transverse septa in the bore of *Serpula heptagona* Hag., as a specific character, but numerous examples of that species in the British Museum (Natural History) from the Mucronata Chalk of Rügen, show that this is an error, for the domed septa have a rimmed foramen on one side and seem to have been formed by some organism which used empty fragments of the serpulid tube for its home.

?Sclerostyla sp.

Fig. 48

The figure shows one of two fragments of heptagonal tube from the London Clay of Highgate: in the absence of associated opercula it would be best to name these ?*Sclerostyla* sp. Two London Clay opercula from Kingsclere are so minute that their characters are indefinite: they might be the earliest stage in opercula of *Turbinia* described below.

Genus: **TURBINIA** H. Michelin, 1845

Turbinia abbreviata (Deshayes)

Figs. 49–50

A full account of this species in the Sables de Cuise of the Paris Basin, of its Thanetian precursor and of their nomenclature, will be found in Wrigley (1950a, pp. 500–3, figs. 1–3). It is known in England only by a few very waterworn specimens in the Lutetian Bracklesham beds (Fisher IX) of Whitecliff Bay (Fig. 49) and in the Cuisian Bracklesham beds (Fisher IV) of the same locality (Fig. 50). The tube (Fig. 49*b*) is heptagonal, with two distinct layers, the inner one often found separately or loose within the outer layer, so that it may be drawn in and out like a telescope. The completely calcareous operculum has two or three superimposed discs (Figs. 49*a*, 50) which are decidedly convex and radiated—these being clear characters of distinction from all the other completely calcified opercula here described.

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[1] Avnimelech aptly compares these to a pile of rimmed drinking glasses.

Genus: **SERPULA** Linnaeus, 1758

Serpula sp.

Fig. 51

Many localities of the Auversian Sables Moyens of the Paris Basin yield a third type of completely calcareous operculum (Wrigley, 1950a, p. 504, fig. 5). A very few specimens of it have been found by J. Turner and H. E. Taylor in the Auversian Upper Bracklesham beds at Medmery Farm, Selsey. The rays of the concave or flattish disc are continued on the cone (Fig. 51) without any of the branching and reticulation which characterise *Sclerostyla mellevillei*. At present the associated tube is not known.

Serpula crassa J. Sowerby

Fig. 52

Serpula crassa J. Sowerby, 1813, p. 73, pl. 30.

Sowerby's holotype from the London Clay at Highgate is still unique. It consists of fifteen associated individuals wholly adhering to a broken specimen of the rare gastropod *Hippochrenes incertus* Wrig. The tubes, which reach a length of 20 mm., are triangular with the characteristic cellular structure well developed on the attached face, the cavities of the cells being filled with iron pyrites. The wholly attached triangular tubes, without any indication of rising to a free, vertical growth, are of a form which is very common amongst serpulids from Jurassic to Recent times, well exemplified by the living *Pomatoceros triqueter* (Linn.) but which affords no clue to the genus of the animal inhabitant. Three of Sowerby's specimens have opercula *in situ*, the largest being shown in Fig. 52. These opercula are fixed in pyrites, precluding their removal from unique material. There are at least three possibilities: (1) the operculum (Fig. 52) is a rayed calcareous disc originally embedded in a chitinous structure which has now disappeared; (2) the visible disc is the top of an operculum like that of *Sclerostyla mellevillei* (Fig. 47); or (3) it is the top of an operculum like that of the Auversian *Serpula* sp. shown in Fig. 51, whose associated tube is unknown. In view of the importance of opercular characters, *S. crassa* must be regarded as imperfectly known until specimens occur with separable opercula.

Genus: **DITRUPA** Berkeley, 1832–4

Ditrupa plana (J. Sowerby)

Figs. 53–5

Dentalium planum J. Sowerby, 1815, p. 179, pl. 79, fig. 1 (London Clay, Bognor (rock)).
Dentalium incrassatum J. Sowerby, 1815, p. 180, pl. 79, figs. 3, 4 (London Clay, Highgate and Richmond).
Dentalium ? *incrassatum* and *D. planum* J. de C. Sowerby *in* Dixon, 1850, p. 117, pl. 14, fig. 2 (London Clay, Bognor (rock)).
Ditrupa plana Etheridge *in* Lowry, 1866, pl. 4.

It is so difficult to distinguish between species of *Ditrupa* by means of the tube, that in the case of fossils one is tempted to name them according to general probability in the absence of any significant morphological characters. *Ditrupa* tubes are found at intervals from the base of the London Clay to the Upper Barton beds, but, by analogy with a multitude of other fossils, this is an improbable range for a single species. *Ditrupa plana* and *D. incrassata* were distinguished by J. Sowerby by differences in the taper and curvature of their tubes but, since the taper diminishes and the radius of curvature increases as the tube grows longer, these characters are not helpful for material which usually is broken and, in embedded specimens, the curvature, being all in one plane, depends upon the mode of exposure. Considered as a familiar fossil of the London Clay, the curved tube of *D. plana* (Fig. 55) is seen to consist of two distinct layers, the inner white and chalky, the outer brown, semi-translucent and composed of radiating crystals when viewed in a cross-section. The outer layer must be calcitic, for it is perfectly preserved where all aragonitic tests have disappeared or it is brown and crystalline when in direct association with the white and chalky tube of an aragonitic *Dentalium*. Figs. 54 and 55 show laminations in the outer layer which bend inward and determine a characteristic constriction at the aperture. This constriction is accompanied to a variable degree by slight swellings which alternate along the tube (Fig. 53).

Distribution. Basement beds of the London Clay at Lane End, Cowcroft, Maidenhead, Crondall, Up Nateley, Reading and Whitecliff Bay, and in most of the fossiliferous localities of the London Clay. It is often abundant, either by itself or in association with Mollusca, when it frequently forms concretions which are very tough when unweathered.

> Deshayes (1826, p. 52, pl. 2, fig. 22) proposed *Dentalium strangulatum* as a new name to avoid the confusion of *D. corneum* Lam. (living), *D. coarctatum* Brocchi (Pliocene) and *D. incrassatum* J. Sby. (Eocene). All these belong to *Ditrupa*. The common usage of *Ditrupa strangulata* (Desh.) for a well-known fossil of the Calcaire Grossier of the Paris basin may well be retained for, although it has no clear distinction from *D. plana*, it belongs to a totally different fauna which has no other species in common with that of the London Clay.

Ditrupa bartonensis n.sp.

Figs. 56–9

Holotype and Paratype (Figs. 56 and 57 respectively)—both from the Barton beds at Barton.

Instead of the irregular swellings and constrictions which characterise the tube of *D. plana*, this is marked by a very close, fine and regular transverse sculpture of raised annulations and incised striae which often are only visible by the aid of a hand lens. In some cases annulations prevail, in others striae, or both may be absent in perfectly smooth tubes with alternations of colour simulating a fine transverse sculpture. At the top of the Bracklesham beds at Huntingbridge and in the Lower Bartons at Highcliff, this species reaches a relatively large size (Fig. 58, where the sinuous appearance is due to defective repair of a broken specimen).

Distribution. Auversian Upper Bracklesham beds of Brook and Huntingbridge. Horizons A3, E and H of the Barton beds at Barton.

No traces of opercula have been found associated with any fossil *Ditrupa*; in the living species they are vesicular with a horny disc which cannot be fossilised.

Ditrupa is exclusively Tertiary and Recent, but its entirely unattached growth, arcuate form and the structure of its tube wall recall the Cretaceous *Hamulus*, already noticed. In *Hamulus*, however, the tube is always externally ridged and is closed by a completely calcified operculum with a rugose cone and a triangular stalk, so that it is not a probable ancestor of *Ditrupa*.

Fig. 59 shows *D. bartonensis*—from horizon F at Barton—deformed by an encysted parasite, this being the only example of the kind which I have noticed.

Genus: **PROTULA** Risso, 1826

Protula extensa (Solander)

Figs. 60–2

Serpula extensa Solander *in* Brander, 1766, p. 12, fig. 12.
Serpula ? *extensa* J. de C. Sowerby, 1844, p. 49, pl. 634, fig. 1.
? *Serpula toilliezi* Nyst and le Hon, 1862, p. 1 (Laeken).
Serpula tenuis (*Teredo* ?) Etheridge *in* Lowry, 1866, pl. 2, *non* J. de C. Sowerby.

The tubes (Fig. 60), which show two distinct layers in cross-sections of corroded material, are slightly tapering and almost straight, sometimes reaching a considerable length with a very small change of diameter (Fig. 61). The thickness of the wall remains almost constant as the diameter increases, so that it looks thicker at small ends. When the surface is perfect (Fig. 60) it has slightly salient annulations. Apical parts showing an attachment are very rare at Barton, one being figured by Sowerby; Fig. 62 shows a bend from horizontal attachment to the upright, free growth, of which nearly all specimens are fragments. The two layers of the tube are distinct in colour, the inner one being whiter than the outer which is laminated and shows traces of the parabolic structure already described.[1] This species has often been confounded with the tubular linings of *Teredo* borings but, apart from the fact that it is never associated with fossil wood, it is easily distinguished by its far thicker wall. *Teredo* tubes are brownish, translucent and apparently calcitic, but *Protula* tubes, though probably calcitic, seem to have had a considerable amount of animal matter in their composition.

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[1] A polished longitudinal section of an unusually well-preserved specimen from Bramshaw shows no trace of a distinction into two layers, or of the presence of any parabolic structure, although these features are plainly seen in corroded material.

Distribution. Auversian Upper Bracklesham beds at Selsey, Brook, Bramshaw (common) and Huntingbridge. Throughout the Barton beds at Barton.

Protula episcopalis n. sp.

Figs. 63–6

Holotype and Paratype (Figs. 64 and 65 respectively)—both from the London Clay at Old Park, Farnham.

In *Protula*, as in *Ditrupa*, in the absence of the animals, no clear specific characters are to be found in their tubes. In a comparison of two very large faunas, Barton species are not found in the London Clay, so where fossil remains are not diagnostic, they may be assumed to be specifically distinct in the two deposits.

The general description of *P. extensa* applies to this species with the distinction that the tubes adhere to one another, both in their early, attached state (Fig. 65) and in their later, upright growth (Fig. 64, which shows the scar left by another individual). A firm attachment to *Ostrea* has been noted. As also in *P. extensa*, the bore of the tube is often excentric because some of the laminae of the outer layer do not completely encircle it (Fig. 66). The outwardly bent edges of these laminae are sometimes seen on their exterior (Fig. 63) where they are covered by a thin skin through which they appear as close incised annulations.

Distribution. In the middle of the London Clay at Old Park, Farnham, and in its lower part at Hendon Tunnel.

The specific name refers to an occurrence in the Old Bishop's Park at Farnham.

Longitubus Howell (1943, p. 161) is a genus based upon long, *straight*, serpulid tubes from the Cretaceous of New Jersey (U.S.A.), where they are found to be useful index fossils for stratigraphical correlation. The description and figures indicate no substantial differences from *Protula* and the max. length of 82 mm. is exceeded by the incomplete *P. extensa* shown in Fig. 61.

3. THE ESSENTIALS OF SERPULID TUBES

The preceding descriptions have several characters in common which serve to define the essentials of a serpulid. It begins as an open-ended apical tube, usually attached to a solid object. This apical growth is thin walled and so easily corroded that it is very rarely found fossilised. The mature tube is formed of two distinct layers of dissimilar substances, the inner compact and porcellanous, the outer laminated, with a skin of calcite which resists corrosion. The bore of the tube is excentric and this discordance is repeated in calcareous opercula, where the stalk is more or less out of centre with the disc. The outer layer of the tube may have oblique pores which do not pierce the inner layer. Where the mature tube adheres to a solid object, cellular structures are formed. These are marked characters of distinction from the shells of vermetid Mollusca of similar forms, whose tests originate in a closed spiral apex and have three layers of aragonite. The latter character serves to distinguish the shell of a molluscan *Dentalium* from the very similar tube of a *Ditrupa*. A longitudinal section of *Dentalium* shows three layers of aragonite in minute prisms which are at right angles to the axis, these layers being elongated cones arranged serially in such a way that three of them are present in any transverse section. No trace of a prismatic structure is seen in *Ditrupa* whose unaltered calcitic tube is always in marked contrast with the chalky transformation of aragonite in *Dentalium* when the two are associated as fossils. In *Ditrupa* the thin rim of the aperture arises from an external thinning of the wall (Fig. 55) but in *Dentalium* it is produced by a terminal expansion of the bore.

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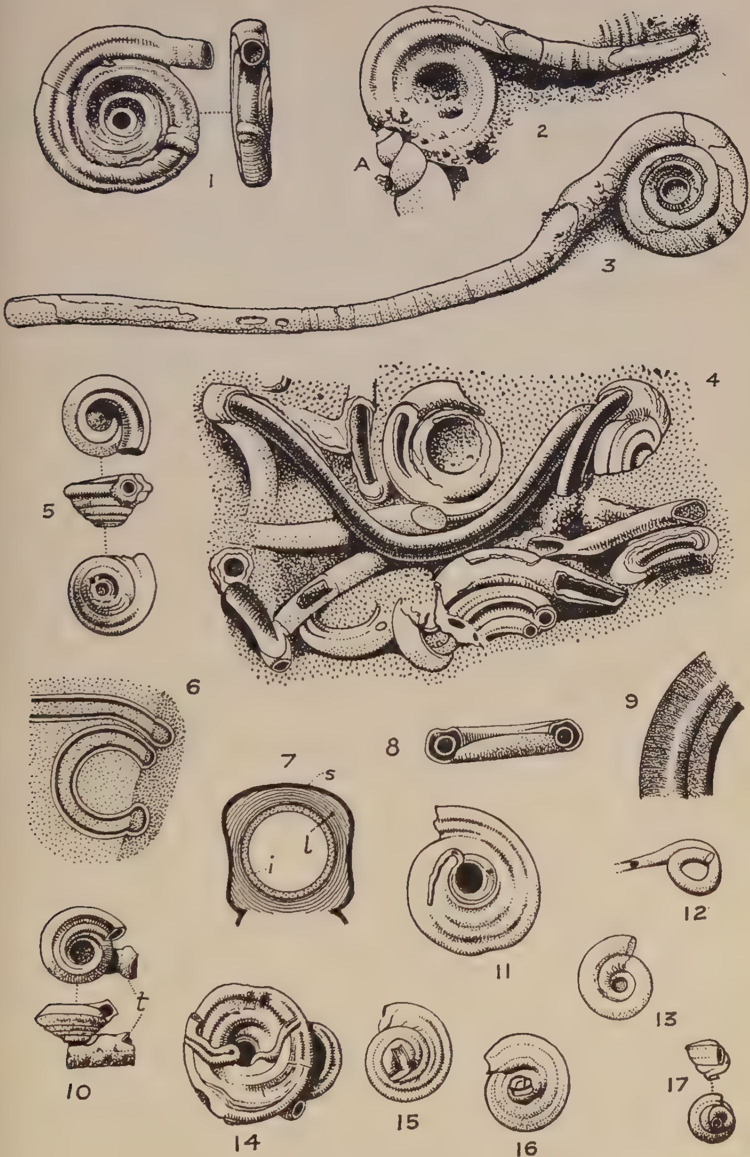
DESCRIPTION OF FIGURES

All the figured specimens, with the exceptions stated, are in the collections of the Geological Dept. of the British Museum (Natural History), whose registration numbers are given.

Figs. 1–15. **Rotularia bognoriensis (Mantell)—London Clay.**

Fig. 1. Aldwick Street, Bognor: upper surface × 1. A.6961.
2. Bognor (rock); upper surface; A—an internal cast of *Aporrhais* × 1. (72097).
3. Bognor (rock); lower surface × 1. (A.6995).
4. Bognor (rock) × 1. (A.6996).
5. Old Park, Farnham × 1. (A.6959).
6. Bognor Rock × 1. (A.2938).
7. Diagram Section based upon Bognor specimens.
8. New Malden × 1½. (A.6987).
9. Highgate; part of upper surface × 3. (A.6994).
10. Worcester Park; *t*—fragment of the free tube of another individual × 1. (A.6966).
11. Aldwick Street, Bognor × 1. (A.6956).
12. Aldwick Street, Bognor; upon an *Anomia* × 2. (A.6967).
13. Aldwick Street, Bognor × 2. (A.6968).
14. Bognor (rock), upper surface × 1. (A.6952).
15. Aldwick Street, Bognor, lower surface × 1. (A.6963).



FIGS. 1–17.—Eocene *Rotularia*

Fig. 16. } *Rotularia spirulaea* (Lamarck) Lower Eocene, Bos
17. } d'Arros near Pau (B.P.) France × 1. (Fig. 16—A.6991; Fig. 17—A.6992).
18. *Spirorbis borealis* (Linné) free larval stages, magnified, after Fewkes: *o*—operculum, *c*—collar, *t*—tube.
19. *Spirorbis borealis* (L.) living, Bembridge. *a*—upper surface, *b*—attached lower surface, enlarged.

Figs. 20–28. **Rotularia bognoriensis (Mantell)—London Clay.**

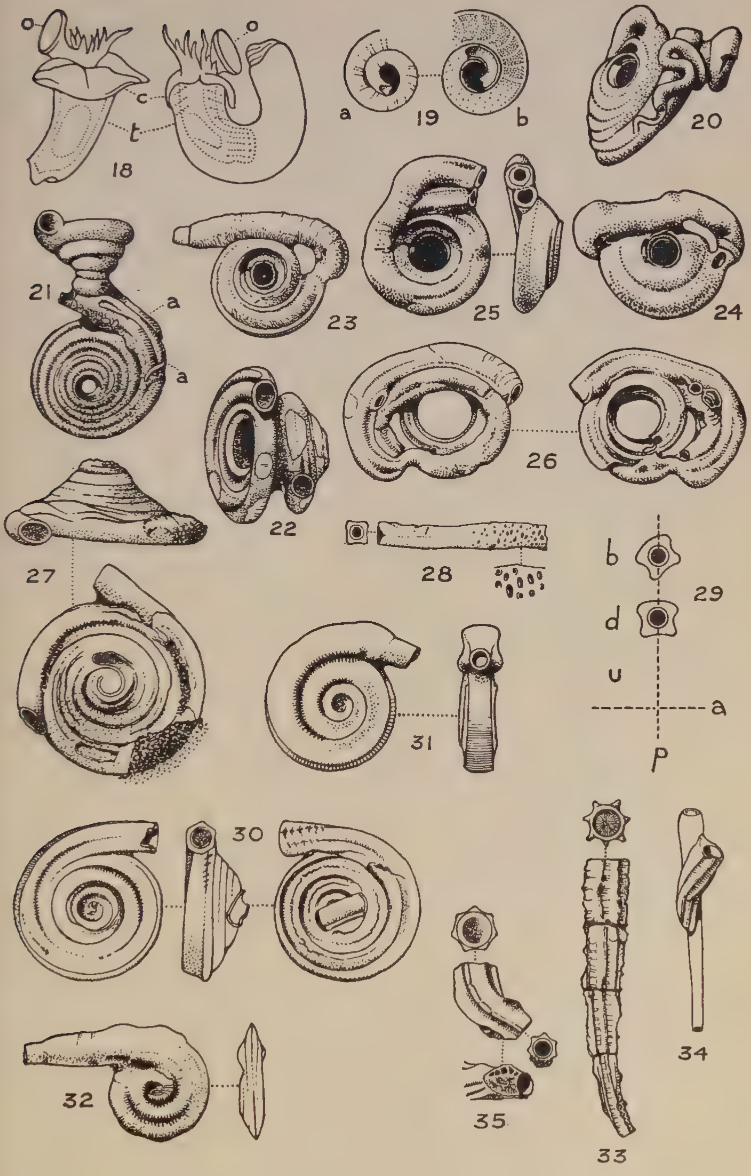
Fig. 20. Aldwick Street, Bognor × 1. (A.6962).
21. Bognor (foreshore); *a*—apical tube × 1. (A.6953).
22. Bognor (foreshore) × 1. (A.6957).
23. Bognor (foreshore), lower surface × 1. (A.6951).
24. Bognor (foreshore), lower surface × 1. (A.6954).
25. Bognor (foreshore), upper surface and profile × 1. (A.6964).
26. Bognor (foreshore) × 1. (A.6955).
27. Bognor (rock) × 1. (A.6997).
28. Whitton (near Twickenham) × 1 and enlarged. (A.6958).

Fig. 29. Diagram: *b*—*R. bognoriensis* and *d*—*R. discoideum*; *p*—*plane* and *a*—axis of coiling, *u*—upper surface.
30. *Rotularia bognoriensis* (Mantell) Cuisian (Herouval horizon) Mt. de Magny (Oise), J. Morellet colln., Paris.
31. *Rotularia discoidea* (Stoliczka) Cenomanian, Utatur group, south India × 2. (A.6990).
32. *Rotularia spirulaea* (Lamarck) lower Eocene, Bos d' Arros, near Pau (B.P.) × 1. (A.6993).

Figs. 33–37. **Sclerostyla mellevillei (Nyst and le Hon)—Barton beds, Barton.**

Fig. 33. Tube with operculum *in situ* × 1, (49775).
34. Juvenile tube attached to *Ditrupa* × 2. (A.6948).
35. Juvenile tube showing cellular attachment × 2. (A.6974).
36. Tube × 2. (A.6976).
37. Operculum × 3, with an enlargement. (A.6949).

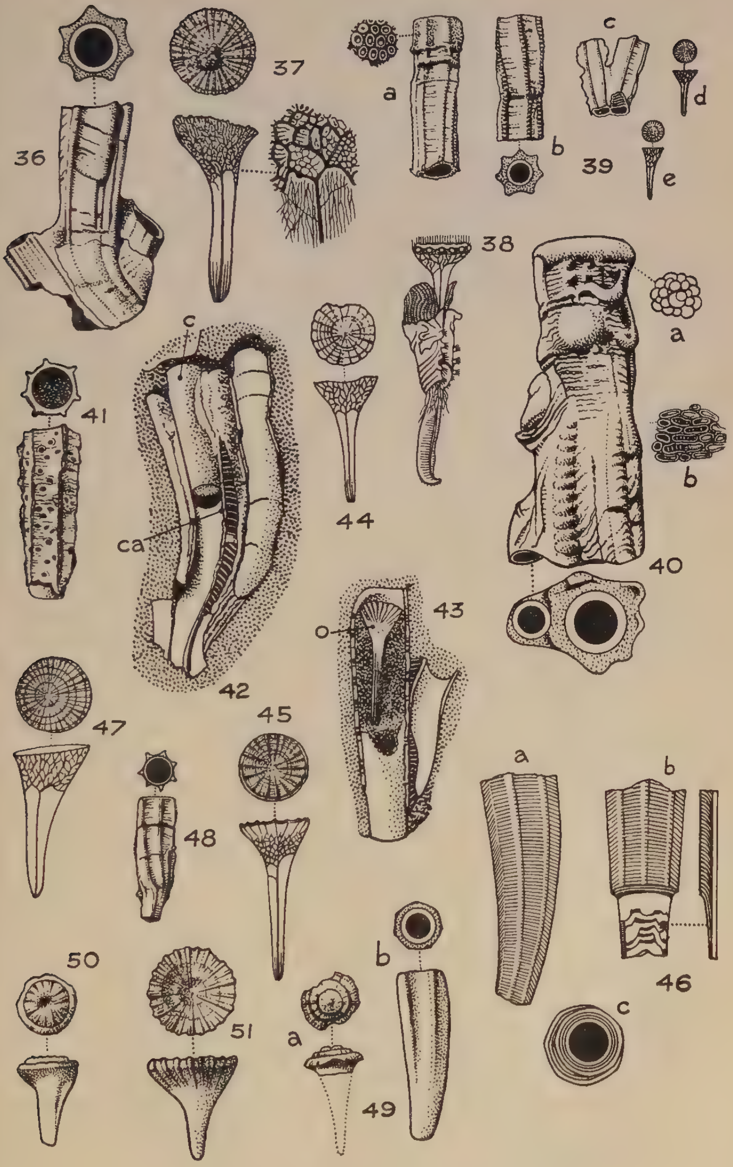
Fig. 38. *Sclerostyla ctenactis* Mörch, Recent, Octavia Bay, Colombia: from a spirit specimen in the collection of the Allan Hancock Foundation, Los Angeles × 3.
39. *Sclerostyla gallica* n. sp.; *a* (with enlargement) *b*, *c*—tubes; *d*, *e*—opercula × 2. Sables de Cuise, Barisis au Bois (Aisne) J. Morellet colln., Paris (ex. G. F. Dollfus).



FIGS. 18–35.—Eocene *Rotularia* and *Sclerostyla*

Fig. 40. *Sclerostyla gallica* n. sp., London Clay (top) Rayleigh, Essex × 2, with enlargements. (A.6970).

41. *Sclerostyla perforata* n. sp., holotype, London Clay, Wokingham × 2. (A.6983).
42. *Sclerostyla perforata* n. sp., London Clay (Modiola Bed) Bracknell; *c*—core of matrix, *ca*—cellular adherence × 2. (A.6986).
43. *Sclerostyla perforata* n. sp., London Clay (Modiola Bed) Bracknell; *o*—operculum *in situ* × 2. (A.6980).
44. } *Sclerostyla perforata* n. sp., London Clay, Wokingham,
45. } opercula × 3 (Fig. 44—A.6960; Fig. 45—A.2822).
46. *Sclerostyla trochoides* (Nyst) Lattorfian, Neerepen (Belgium) tubes × 2.
47. *Sclerostyla trochoides* (Nyst) Lattorfian, Grimmertingen (Belgium), operculum × 2. (Museé Royal d'Histoire Naturelle, Brussels, with the original of Fig. 46).
48. ?*Sclerostyla* sp., London Clay, Highgate × 1. (A.6972).
49. *Turbinia abbreviata* (Deshayes) Lutetian Bracklesham (Fisher IX), Whitecliff Bay; *a*—operculum, *b*—tube × 8. (A.6971).
50. *Turbinia abbreviata* (Desh.) Cuisian Bracklesham (Fisher IV), Whitecliff Bay, operculum × 8. (A.6978).
51. *Serpula* sp., Auversian Bracklesham, Medmery Farm, Selsey, operculum × 8. (A.6975).
52. *Serpula crassa* J. Sowerby, London Clay, Highgate, part of the holotype × 2. (A.6722).
53. *Ditrupa plana* (J. Sowerby) London Clay (div. 5) Tolworth × 1. (A.6984).
54. *Ditrupa plana* (J. Sby.) London Clay, Alum Bay × 1 and enlarged. (A.6985).
55. *Ditrupa plana* (J. Sby.) London Clay (div. 3) Worcester Park, section × 4. (A.6973).
56. *Ditrupa bartonensis* n. sp., holotype, Barton beds, Barton × 1. (A.6981).
57. *Ditrupa bartonensis* n. sp., paratype, Barton beds, Barton × 1 and enlarged. (A.6982).
58. *Ditrupa bartonensis* n. sp., Auversian Bracklesham Huntingbridge × 1. (A.6989).
59. *Ditrupa bartonensis* n. sp., deformed by a parasite, Middle Bartons F, Barton × 2. (A.6977).
60. *Protula extensa* (Solander) Middle Bartons E, Barton × 1. (A.6988).
61. *Protula extensa* (Sol.) Barton beds, Barton × 1. (Sedgwick Mus., C.12437).
62. *Protula extensa* (Sol.) Auversian Bracklesham, Bramshaw × 2. (Sedgwick Mus., C.12419).



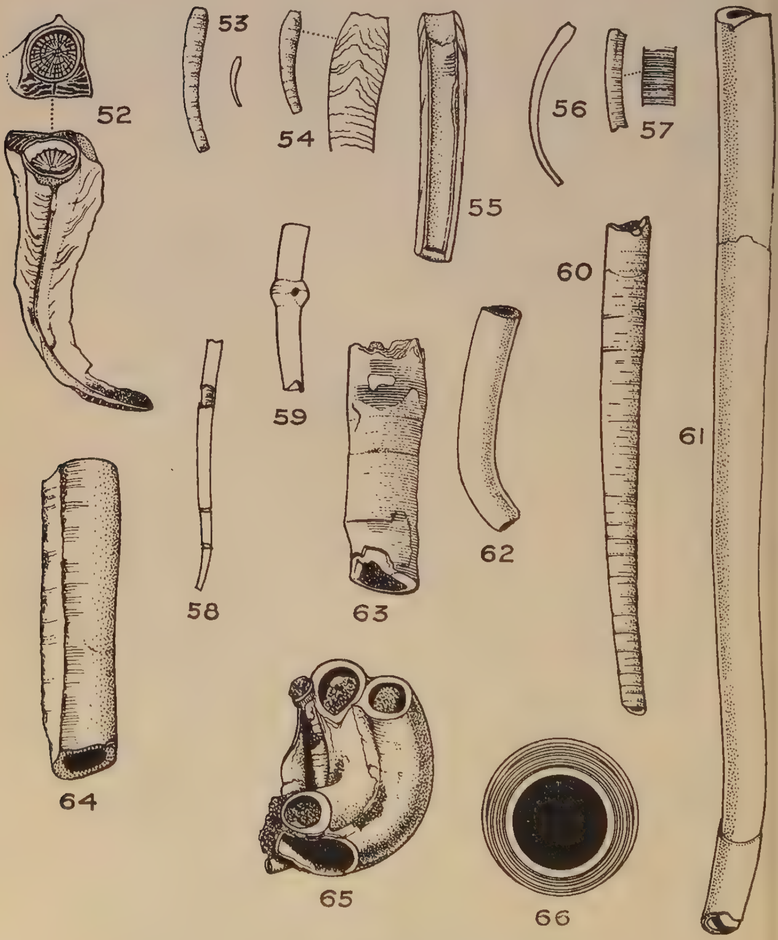
FIGS. 36–51.—*Sclerostyla* and *Turbinia*

Fig. 63. *Protula episcopalis* n. sp., London Clay, Old Park, Farnham × 1. (A.6969).

64. *Protula episcopalis* n. sp., holotype, London Clay, Old Park, Farnham × 1. (A.5159).

65. *Protula episcopalis* n. sp., paratype, London Clay, Old Park, Farnham. (A.5156).

66. *Protula episcopalis* n. sp. London Clay, Old Park, Farnham; section × 2. (A.6979).



Figs. 52–66.—Eocene *Serpula*, *Ditrupa* and *Protula*

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SUMMER FIELD MEETING IN NORWAY

7–22 August, 1950

By PROFESSORS O. HOLTEDAHL, T. F. W. BARTH and N-H. KOLDERUP, and DOCTORS A. KVALE and J. F. KIRKALDY

[*Received* 20 *January* 1951]

CONTENTS

PAGE
I. Daily Itinerary (By N-H.K., A.K. and J.F.K.) 203
II. Geology of the District around the Upper Part of the Oslo Fjord (By O.H. and T.F.W.B.) 211
Bibliography to Part II 213
III. Geology of the Area Between the Finse District and the Bergen Arcs (By A.K.) 214
  A. The area east of the Hardangerfjord 214
  B. The area west of the Hardangerfjord 217
  C. Structure 220
  D. Geomorphology 222
References to Part III 223

I. DAILY ITINERARY

Report by Professor N-H. Kolderup, Dr. A. Kvale and Dr. J. F. Kirkaldy

FORTY-THREE members assembled in Oslo on the evening of 7 August, the majority of the party having travelled by the S.S. *Suecia* from Tilbury to Gothenburg and thence by rail to Oslo. In part the programme followed that arranged for the last Field Meeting to Norway in 1934 (*Proc. Geol. Assoc.*, **45**, 307–88). Only those days which were spent in fresh country have been described below in detail; for the other days, page references are given to the Report already published in these PROCEEDINGS (*op. cit.*)

Tuesday, 8 August

Directors: Professor O. Holtedahl, Professor T. F. W. Barth and Professor L. Störmer.

At the Oslo Geological Museum, an introductory talk on the geology of the area was given and the party then examined the fine collections and the relief model of the region. Coaches were taken to the Holmenkollen Restaurant, where lunch was provided by the Norsk Braendselolje A/S. Dr. G. W. Himus, Vice-President, replied to speeches of welcome from the Managing Director, Mr. Gudbrand Askvig and Professor Holtedahl. The ascent to the summit of the mountain was made by railway. After studying the magnificent view and exposures in akerite, the party walked some way down the mountain (*op. cit.*, p. 378) before taking the train back to Oslo.

Wednesday, 9 August

Directors: Professor O. Holtedahl and Professor L. Störmer.

The programme for the Inner Oslo Fjord was the same as that on 3 August 1934 (*op. cit.*, pp. 378–9). Lunch was kindly provided by Mr. Holst, Director of the Cement Works at Slemmestad.

Thursday, 10 August

Directors: Professor O. Holtedahl, Professor L. Stormer and Professor I. Oftedal.

In large part the programme followed that for the visit to the Lier Valley on 4 August 1934 (*op. cit.*, p. 379). After a sandwich lunch kindly provided by Mr. Throne-Holst, the opportunity was taken to examine very fossiliferous exposures of Llandoverian strata (Pentamerus Limestone) in the cliffs of his estate at Rytteraker.

Friday, 11 August

Directors: Professor O. Holtedahl, Professor T. F. W. Barth and Mr. J. A. Dons.

Coaches were taken to Grefsenkollen to examine nordmarkite cutting Ordovician strata, which had been altered to several varieties of hornfels. The presence of a small area of rhomb porphyry and basal Permian sediments, between the nordmarkite and the hornfels, was demonstrated. To the north-east quarries showed very striking and large xenoliths in the nordmarkite. These xenoliths of lava rocks, etc., were stated to be subsided parts of the roof. The walk continued through most beautiful woodlands, passing from the nordmarkite across red argillites to crags of Permian conglomerate, which form the central part of the subsided Alnsjø complex. From the crags, Professor Holtedahl pointed out the chief topographic features of the complex and discussed its mode of formation. The return to Oslo was made in the early afternoon by public bus. In the evening members assembled at the British Embassy, where they were entertained to a cocktail party by the Ambassador, Sir Lawrence Collier, and Lady Collier.

Saturday, 12 August

This was a free day and members welcomed the opportunity to visit the Viking Ships, the Folkemuseum, the 'Kon Tiki' raft, the 'Fram' and other well-known places in Oslo. In the evening those members of the party who were staying at the Misjonshotel entertained to dinner those Directors who would not be travelling with the party from Oslo. The thanks of all members were conveyed to Professor T. F. W. Barth, Professor I. Oftedal and Mr. J. A. Dons by Professor S. E. Hollingworth and Mr. A. J. Butler.

Sunday, 13 August

Director: Professor O. Holtedahl.

The journey from Oslo to Hamar was made by coach and as in 1934 (*op. cit.*, p. 384), Professor Holtedahl demonstrated and described the glacial geology of the route, special attention being paid to the neighbourhood of Hauerseter. During the drive along the beautiful Lake Mjøsen, a roadside exposure in Pre-Cambrian gneiss cut by pegmatitic dykes was examined.

Monday, 14 August

Director: Professor O. Holtedahl and Professor L. Störmer.

A visit was paid to the ruins of Hamar Cathedral and the adjacent section in the Orthoceras (Lower Ordovician) Limestones. Then, as in 1934 (*op. cit.*, 384), a number of fine sections in the various members of the Sparagmite Formation were examined around Moelv, including the spectacular and convincing exposure of tillite in the railway cutting. The drive was continued to Lillehammer, where a brief visit was paid to the Folkemuseum. Time was now running short and only one short halt was made during the drive to Gjovik, to see the remarkably contorted Biri Limestone at the Helgeberget Peninsula.

Tuesday, 15 August

Directors: Professor O. Holtedahl and Mr. J. A. Dons.

From Gjövik the coaches drove through Vardal across the high ground to Fluberg on the Randsfjord, where recent road widening had exposed slightly altered Alum Shales (Cambrian). Professor Holtedahl described the features of the zone of imbricate structure. The drive continued down the eastern side of the lake to near the Brandbukampen, where Mr. Dons was waiting with specimens of a very striking intrusion breccia composed mainly of maenaite. Below the Brandbukampen, the party was most hospitably entertained to lunch by Mr. Hans A. Eid at his country house. After lunch the coaches drove to the foot of the Sölsberget (a plug of 'Oslo essexite'). Mr. Dons described the features of the extensive view seen from the summit. During the drive to Hönefoss, the party passed large glaciomarine terraces at the southern end of the Randsfjord. During dinner Professor S. E. Hollingworth, Mr. P. Evans and Canon A. F. Smethurst conveyed the thanks of the party to Professor and Mrs. Holtedahl, and to Professor and Mrs. Störmer.

Wednesday, 16 August

Director: Professor L. Störmer.

This was the only day of the Field Meeting when there was really bad weather. The party travelled by train from Honefoss to Finse. After arriving there in the mid afternoon, a considerable number of members, undeterred by torrential rain and strong wind, walked across the moraines and examined the crevasses and other features of the lowest part of the Hardangerjökul, but the weather conditions prevented a long stay on the glacier.

Thursday, 17 August

Directors: Professor L. Störmer, Professor N-H. Kolderup and Dr. A. Kvale.

Before leaving Finse, the party examined the mountains north of the railway station. The Pre-Cambrian basement, the Cambro-Ordovician phyllite formation, and the overthrust masses of granitic and gneissic rocks could be clearly distinguished even at a distance.

After travelling by train to Haugastøl the party went by coach across Hardangervidda. At Haugastøl a peat bog was visited. Although lying above the present timberline, this bog contains roots of pine trees which grew in this area during the warm post-glacial (Climatic Optimum) period some 3–5000 years ago.

During the drive across Hardangervidda the party had a splendid view of the present-day peneplain with a gently undulating surface, while the coaches crossed the—also undulating—sub-Cambrian peneplain, which separates the basement rocks from the phyllite formation. Stops were made at Örterdalen to study the Telemark granite with amphibolite, and at Dyraheii to examine the phyllite. A few kilometres further west the road summit, at about 1240 m., was passed, and the road gently descended the broad, open valley leading to Fossli, a valley that most likely has preserved its pre-glacial character.

Soon the sub-Cambrian peneplain was passed and the rest of the day was spent in Pre-Cambrian rocks. At Fossli the party was met by Professor Dr. N-H. Kolderup, who, after luncheon, explained the geomorphology of the area. The steep-sided and most spectacular Maabödal, whose upper part is a canyon with nearly vertical walls, has been cut deeply into the old pre-glacial valley. The excavation of the younger valley began after a late Tertiary uplift of the Scandinavian land-mass, and the present valley surface is formed in part by glaciers, in part by sub-glacial rivers, and in part by interglacial and post-glacial erosion.

The coaches descended the winding road to the bottom of Maabödalen, and after a short drive the sea was reached at Eidfjord. A large terminal moraine lies across the valley west of the lake Eidfjordvatn. The moraine is most likely contemporaneous with the great Ra-moraines in eastern Norway, formed about 10,000 years ago.

From Eidfjord the road followed the Hardangerfjord to Kinsarvik, where there is another moraine of the Ra period. Beyond Kinsarvik an area of supracrustal rocks of the Pre-Cambrian Telemark formation was entered. Stops were made to collect metadacite, metabasalt and quartzite, the last halt being close to the hotel at Lofthus.

After dinner some of the party walked about one km. east of Lofthus to examine a fairly large rock-fall, which had occurred a few days before.

Friday, 18 August

Director: Dr. A. Kvale.

In the morning the party returned to Kinsarvik by coach, crossed the Hardangerfjord by ferry and continued by coach from Kvandal southward along the Hardangerfjord.

At Kvandal a post-glacial marine terrace was seen to be well developed. The first part of the journey from Kvandal traversed the Pre-Cambrian granitic rocks. At Lussand the contact between the granite and the Cambro-Silurian phyllite was studied. In the uppermost ten metres the granite was deformed, its planar structure being parallel to the contact.

About four km. south-west of Lussand the phyllite formation is overlain by an overthrust complex of igneous and metamorphic rocks, the contact being seemingly conformable. A variety of rock types belonging to the overthrust mass was passed, and at Fyksesund Cambro-Ordovician rocks below the nappe were again encountered. Besides phyllite these rocks comprise altered volcanic and intrusive rocks. Green schists and green conglomerates were studied at Berge.

After luncheon at Norheimsund the party continued through Steinsdalen Valley, the bottom of which consists of marine terraces. Towards the west the valley ends fairly abruptly, but a canyon, Tokagjel, is cut deeply into the adjacent mountain. Having ascended the beautiful canyon the coaches continued across the Kvamskogen area, where the geological structure is rather complicated. Two nappes occur, each consisting of supposedly Pre-Cambrian supracrustal and intrusive rocks, intruded by Caledonian granite, and with a zone of mica-schist between them. The nappes have been thrust towards the east-south-east, and the rocks in the nappes, together with the mica-schist between them and below them, illustrate linear structures parallel to the direction of movement. Near the thrust front, this lineation is folded along axes which are parallel to the front. The folding must, therefore, belong to a late stage of the overthrusting, and the lineation must be older than this stage; for as it is parallel in all tectonic units it must have been produced during the thrusting. Both the lineation and the cross-joints perpendicular to it are very prominent and clearly visible in the landscape. Conformity exists along all contacts between the tectonic units.

Stops were made at both ends of Tokagjel to study the geomorphology, the crumpled phyllite, and the green schist of volcanic origin; at Røyrli, where the main tectonic units in the neighbouring area were pointed out, and also one km. west of Røyrli, where the mica-schist between the nappes and its contact with the metadacite of the lower nappe crossed the road.

The night was spent at Kvamshaug.

Saturday, 19 August

Directors: Professor N-H. Kolderup and Dr. A. Kvale.

Driving westward from Kvamshaug through the lower nappe, the party halted at Brattefoss to examine the metadacite with its stretching and its cross-joints, along which a canyon has been eroded.

The next stop was made at Fröland, where the area of overthrust rocks join the Bergen arcs. The strata, which dip gently through the Kvamskogen area, here rapidly increase in dip, and the contact with the arc system is vertical. The mica-schist between the nappes is reduced in thickness to a few metres, and 1–2 km. north of the highway it is squeezed out completely whilst the thickness of the upper nappe is greatly reduced.

The party had now entered the complex of curved zones of Cambro-Silurian rocks, known as the major Bergen Arc. A halt was made at Björkhaug, to examine a body of acid intrusive rocks in the lower series of mica-schist. The rocks near Björkhaug are soda-lime-dominated igneous rocks, which in Norway are generally called trondheimites. But the same zone also includes light flinty rocks supposed to be metamorphosed volcanic rocks of dacitic composition. The contact against the schists is one of thrusting, and no signs of metamorphism due to igneous action have been established here.

The next stop was at Grasdal bridge, where the road cuttings afforded good exposures of the upper part of the series. Green schist, the green polygenetic conglomerate known as the Moberg conglomerate, trondheimite, and shales with limestone of Ashgillian age were examined. The green schists, supposed to be originally volcanic rocks, are perfectly recrystallised as hornblende- or epidote-chlorite-bearing schists. The green polygenetic conglomerate is mostly very contorted. The trondheimite, a Caledonian intrusive rock, was seen to have a gneissic structure. The limestone at Grasdal is a red crystalline rock, but belongs to a zone of fossiliferous limestone, with corals and other fossils, indicating an Upper Ordovician age.

At Gulbotten tourist station, where the party had lunch, the same limestone is a grey rock with some very scarce traces of fossils.

The road leads on along the direction of strike. In the valley leading down to Trengereid at Sörfjorden some green, originally clastic rocks were inspected. These rocks, which Reusch in 1882 called 'chloritic sparagmite', are now explained as the result of a diagenesis of detritus from green volcanic and intrusive rocks. At Trengereid the road leaves the Major Arc, and enters the large complex of rocks of the Bergen–Jotun kindred, or anorthosite-charnockite rocks. From the road which leads along the shore of Sørfjord, views of the large island Osteröy, an island that lies far inland, were seen. Only a narrow outlet allows the communication between its surrounding fjords and the sea.

A stop at the farm Ytre Arna gave the opportunity to examine a body of serpentine with needles of actinolite. This body lies in the Bergen–Jotun rocks, and the serpentine is believed to be a member of this kindred.

After the party had passed the industrial village of Arna, the anorthosites near the lake Gaupaasvatn were studied. In the exposures along the roadside, and in blocks, all the peculiar types of anorthosites were found. The variation as to facies ranges from granulite facies, with fresh plagioclase, pyroxene, garnet, scapolite, spinel, and corundum, to saussurite-anorthosites. The existence of various types of orbicular structure as well as reaction phenomena were ascertained.

The last halt was made near Aasane church, where intermediate members of the Bergen–Jotun kindred, mangerites and related rocks, were studied. At this locality they are only in a metamorphic state.

From here the road proceeds to the shore of the Bergen Fjord and offers a view of the city of Bergen with its characteristic position on the Cambro-Silurian schists, locked on both sides by the mountains formed of gneisses.

Sunday, 20 August

Director: Professor N-H. Kolderup.

The party left for Os in coaches. A stop was made at Vallaheiene, where the road crosses a zone of garnetiferous mangerites, and where also silexite, the characteristic quartz rock connected with the anorthosites, could be seen.

In the valley, Hegglandsdal, a locality was visited where blocks of fossiliferous limestone could be hammered. The party succeeded in securing specimens from this exposure, a place famous as the first whence fossils were described from a complex of metamorphic rocks.

Before lunch at Solstrand the quartziferous mica-schists, the lowest stratum of the series of the Arc, were visited. Dykes and veins of trondheimites were seen to intersect the schists.

After lunch the party proceeded on foot to the village of Os, where one had a splendid view of the igneous massifs across the Björnefjord anticline. Far away the top of the glacier Folgefonn, an old acquaintance from Lofthus, was seen glittering in the sun. Then followed a walk through the whole series of strata of the Major Arc. They correspond to the strata passed the day before, but in Os the degree of metamorphism is lower, and the series is more complete.

The green schists, originally volcanic rocks, are perfectly recrystallised here too, but traces of the original bedding are evident. Some layers of argillaceous sediments, now mica-schists, were also seen. The Moberg Conglomerate in an exposure at the roadside is so contorted that it could scarcely be recognised as a conglomerate. Fifty metres away from this, measured along the direction of strike, the conglomerate structure was not only recognisable but perfectly distinct. The trondheimite has large augen of quartz, protruding on weathered surfaces. The exposure also showed basic inclusions. The shales and fossiliferous limestones at Lake Ulvenvatn were visited. Along the shore of Lake Ulvenvatn the party passed the green clastic rock, here exposing an unmistakable conglomerate. (See also *Proc. Geol. Assoc.*, 1943, **45**, 386–7.)

From here the track led into the body of saussurite-gabbro, separating the Cambro-Ordovician and the Silurian strata. The appearance of the gabbro varies from coarse types with dark hornblende crystals to fine-grained dark green rocks. Numerous zones of crushed rock were also observed.

Having passed the gabbro, the party arrived at the upper strata, proved, by the fossil content of the shales, to be of Lower Silurian (Llandoverian) age. The quartzites seen were of a distinctly clastic nature, with the original bedding well preserved. The conglomerates, however, contained undeformed pebbles mainly of quartzite. The pebbles have kept their shape as boulders. The black shale includes small patches of limestone with fossils, but the party did not succeed in finding any.

During the whole excursion the geomorphology of the landscape was demonstrated. The geological structure, too, is clearly visible in the landscape, for all the valleys are excavated in the direction of the strike, the softer rocks forming the valleys and the more resistant, the hills. The party entered the coaches on the raised beach of Ulven for return to Bergen for dinner. This raised beach, fifty-eight metres above sea level, marks the marine limit in this area.

Monday, 21 August

In the morning the party met at the Geological Museum, where the museum and the collections were demonstrated. Many of the members also paid a visit to the Geological Institute of the University in order to discuss problems of general interest.

The remainder of the day was free, members assembling again in the evening for dinner at the Flöyen Restaurant, overlooking the City of Bergen. At this farewell dinner, Professor and Mrs. Kolderup and their daughters and Dr. and Mrs. Kvale were the guests, and to them Professor S. E. Hollingworth and Mr. A. J. Butler voiced the thanks of the party. Mr. M. L. Larman then thanked Dr. J. F. Kirkaldy, who had acted, with the assistance of Mr. D. W. Humphries, as Secretary for the Field Meeting. Just before the dinner, Professor Kolderup and Mr. Butler had given from the Bergen Broadcasting Station a short account of the Association's most instructive and enjoyable visit to Norway.

Tuesday, 22 August

The majority of the party sailed for Newcastle in the S.S. *Venus*

II. GEOLOGY OF THE DISTRICT AROUND THE UPPER PART OF THE OSLO FJORD

By Professors O. Holtedahl and T. F. W. Barth

Since 1934 a considerable amount of work has been devoted to the study both of the Pre-Cambrian, occurring to the south-east, south and south-west of Oslo, and of the Permian igneous rocks to the north-east, north and north-west. A revised geological map, in the scale of 1: 25000 and covering an area of about 40 km. in the north–south and about 30 km. in the west–east direction, has been prepared in manuscript. This map is based on recent field investigations and shows many new features compared with the Brögger-Schetelig maps.

Pre-Cambrian. This has been studied by C. Gleditsch who has distinguished and mapped a large number of different types of rocks: leptites (in part primarily quartz-porphyries), gneisses of various types, gneiss-granites, etc. The structural trend of the rocks is largely rather irregular and curving, the north–south trend less dominating than was previously believed to be the case.

The Permian igneous rocks, their mode of occurrence, petrology and systematic classification have been subjected to revised studies by a number of investigators since 1934 (see bibliography, p. 213).

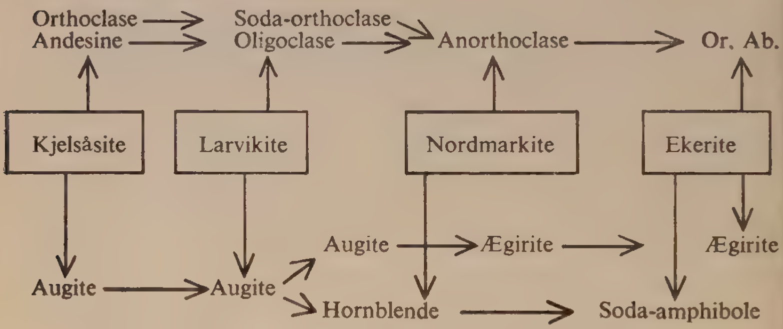
The rocks have been reclassified according to modern usage, and the interpretation of their evolution brought into conformity with modern petrological knowledge.

The petrographic types of the deep-seated rocks of the Oslo Region are as follows:

THE OSLO ROCKS

	Oslo name	Type name	Area, km^2	%
Oldest series	Oslo essexite	Olivine-gabbro	15	0·3
		Hyperite		
		Alkalic diorite		
Main series	Kjelsasite	Syenodiorite, augite-monzonite	253	5·0
	Larvikite	Augite-monzonite	1670	32·8
	Lardalite	Nepheline-monzo-syenite	65	1·3
	Nordmarkite (Granite)	Alkali syenite	1425	28·0
	Ekerite	Aegirite-alkali-granite	821	16·1
Younger intrusion	Granitite	Biotite-granite	840	16·5
			5089	100·0

The Oslo essexite series does not include any true essexites, and the younger granitite (=Drammensgranite) is not 'alkaline' in its relations. The members of the 'main series' (Kjelsasite–Ekerite) are co-magmatic, the parental magma probably possessing a syenitic composition and the evolution taking place mainly according to the following diagram:



In the formation of lardalite the evolution has proceeded with decrease in silica. This cannot be shown in the above diagram but is illustrated by Fig. 1 which, from left to right, displays the systematic

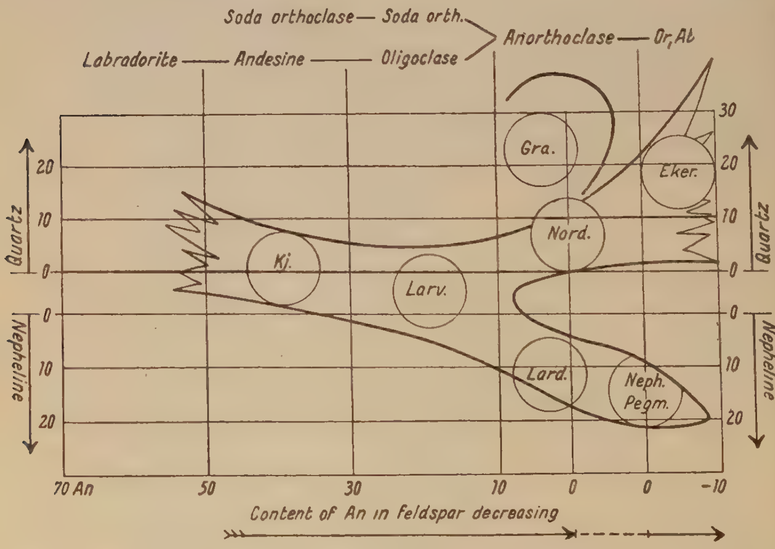


FIG. 1.—The mutual relations of the chief types of deep-seated rocks of the Oslo area. (*N.B.* Oslo-essexite is not included.)

position and the mutual relations of all the principal types of deep-seated rocks, except the Oslo essexite, and indicates the course of differentiation followed by the Oslo magma.

New studies on dyke rocks and on effusive rocks have brought to light many interesting details. It is worthy of special note that the phenocrysts of the rhomb-porphyries are not pure alkali felspars but contain 30–40 per cent anorthoclase.

Structural features. The geology of the area of 'cauldron subsidence' north-west of Oslo (see p. 350 and map, pl. 29, *op. cit.*) has been worked out in detail. Lavas belonging to the upper part of the Oslo volcanic sequence have, together with largely fine-grained intrusive felsitic rocks and igneous breccias, been faulted down against Cambro-Silurian, older lavas, larvikite, etc., with, for long distances, a thick nordmarkite dyke along the border.

The Alnsjö area north-east of Oslo (mentioned p. 348 and 351 *op. cit.*) with basaltic lavas, agglomerates and also rocks of sedimentary origin lying in nordmarkite, must be regarded as a fragment of a once much larger subsided mass, the southern border showing ring fracture character. In the nordmarkite zone to the south, between the said border and the south border of the plutonic mass, there are a very great number of inclusions of partly Cambro-Silurian hornfels, partly rocks belonging to the basal part of the Permian supracrustal sequence. These inclusions are arranged in such a way that we must assume that they have dropped down from the roof that once covered the nordmarkite magmatic body. Close to the nordmarkite contact the adjacent bed rock has been subjected to interesting tectonic deformations, as in the Grefsenås.

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I. HOLTEDAHL, O. 1943. Some structural features of the district near Oslo.
II. BARTH, F. W. 1944. Systematic petrography of the plutonic rocks.
III. SÆTHER, E. 1945. The southeastern part of the Bærum-Sörkedal Cauldron.
IV. BARTH, T. F. W. and B. BRUUN. 1945. Fluorine in the Oslo petrographic province.
V. BARTH, T. F. W. 1945. Falkenstenite, a new zeolite in variolite from Horten, and the surface conditions during the effusion of the oldest Permian lavas.
VI. OFTEDAHL, CHR. 1946. On akerites, felsites, and rhomb porphyries.
VII. SÆTHER, E. 1946. The area of lavas and sediments in Nittedal.
VIII. ————. 1947. The dykes in the Cambro-Silurian Lowland of Bærum.
IX. OFTEDAHL, CHR. 1948. The feldspars.

III. GEOLOGY OF THE AREA BETWEEN THE FINSE DISTRICT AND THE BERGEN ARCS

By Dr. Anders Kvale

The tectonic development has been rather different in the eastern and in the western parts of this area, and it is therefore convenient to describe these parts separately.

A. The area east of the Hardangerfjord

As in the Finse district the rocks may be divided into three main divisions:

1. The Pre-Cambrian rocks
2. The Cambro-Silurian schists
3. The overthrust rocks

1. THE PRE-CAMBRIAN ROCKS

These rocks may be divided according to age into the following groups:

- (a) The Telemark formation
    - (i) Sedimentary and volcanic rocks
    - (ii) Intrusions of gabbro, quartz-diorite and soapstone.
- (b) Younger granitic rocks, which have partly migmatised the older rocks.

(a) *The Telemark formation* occurs on both sides of the Sørfjord in Hardanger. It has no direct connection with the type area of Telemark in eastern Norway, but the rock types are very similar, their Pre-Cambrian age is well established and there can hardly be any doubt as to the identity of the formation.

The sedimentary rocks are quartzite and quartz-schist with quartzite conglomerate. They occur south of Lofthus, especially on the west side of Sørfjorden. The quartz-schists contain varying amounts of muscovite and potash felspar.

The volcanic rocks are metabasalts, metadacites, metarhyolites, and tuffites. The metabasalts are hornblende-plagioclase-schists with some epidote and usually with small amounts of biotite. The metadacites are quartz-biotite-oligoclase-schists, usually with epidote and partly containing small amounts of hornblende. The metarhyolite contains quartz, potash felspar, albite or acid oligoclase, and biotite, commonly with small amounts of epidote and muscovite. The tuffites are banded rocks. The bands vary in width from 1 to 10 cm. and consist of hornblende, chlorite and plagioclase, or of quartz and plagioclase, or mainly of epidote.

The supracrustal rocks have been intruded by serpentine, saussurite-gabbro and hornblende-quartz-diorite.

(b) *Granite*. The youngest Pre-Cambrian rocks in the area are the granitic. There are several types, the most common type being a coarse-grained rock which partly has a porphyritic texture. These younger granites surround the Telemark formation on all sides and cover vast areas in southern Norway. Minor bodies of supracrustal

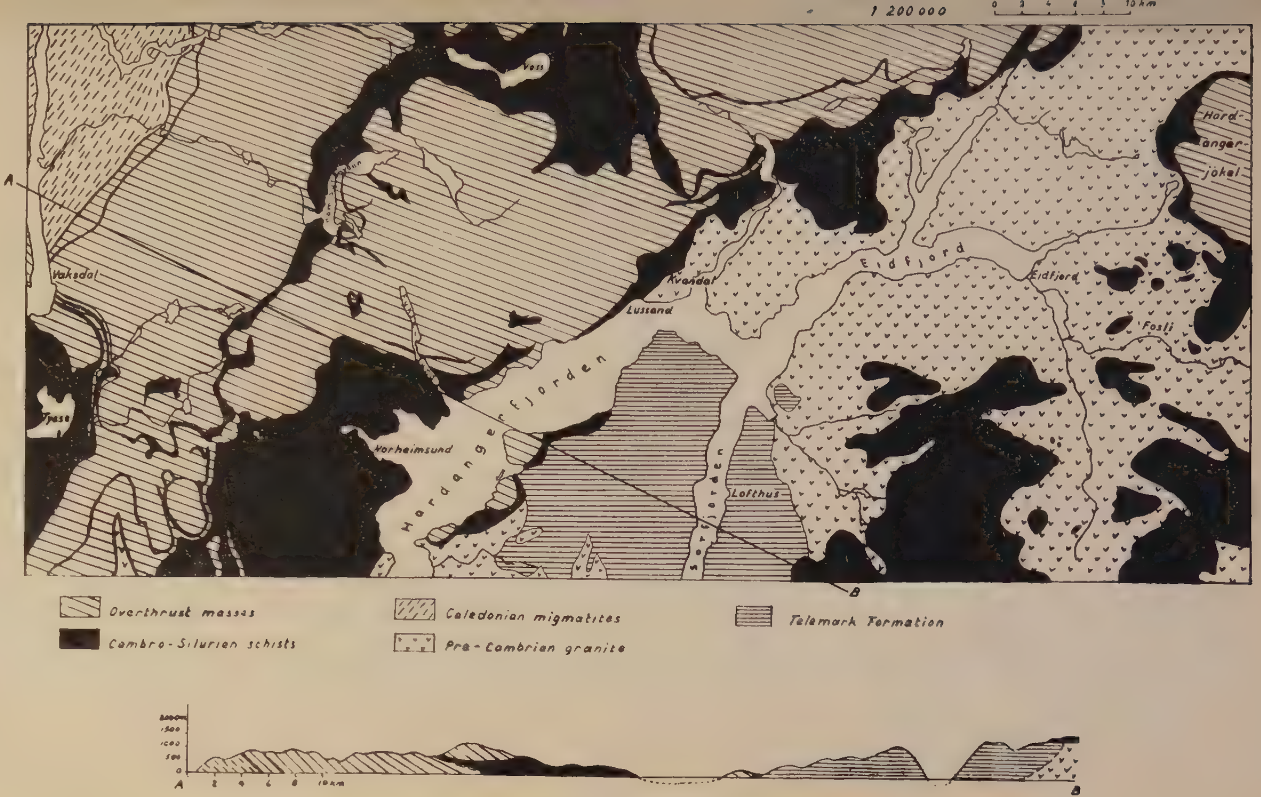

FIG. 2.—Geological map of the area between the Finse district and the Bergen arcs.

rocks, especially metadacite, occur in several places outside the Sørfjord area, *e.g.*, along the road between Kinsarvik and Eidfjord. One might say that the supracrustal rocks are floating in a sea of granite.

Within the granite some areas of gneisses and migmatitic rocks occur. The gneisses were considered by Reusch and other early investigators to be older than the Telemark formation. At least some of the gneisses may, however, be migmatised and partly assimilated rocks of the Telemark formation. The granites themselves have in recent years been regarded by Barth and others as formed by the granitisation of rocks belonging to the Telemark formation. The scattered occurrences of more or less altered rocks of the Telemark formation in the granite area may be said to be in accordance with this view.

2. THE CAMBRO-SILURIAN SCHISTS

These schists are described by Mr. Rosendahl in his article on the geology of the Finse district (*op. cit.*, p. 368). They have been thrust above the Pre-Cambrian basement, and the stratigraphic sequence is therefore in many places uncertain.

3. THE OVERTHRUST ROCKS

Over large parts of Hardangervidda there occur above the Cambro-Silurian schists a series of granite, gneiss and other metamorphic rocks, which evidently have been thrust above the schists, commonly with a zone of mylonite along the thrust-plane. The age of these rocks is not known. They may be partly Pre-Cambrian, partly Caledonian.

In the north-western part of Hardangervidda the overthrust rocks are absent in most places, probably removed by erosion, but they occur in the higher parts of Hardangerjøkulen.

CALEDONIAN DEFORMATION OF THE PRE-CAMBRIAN BASEMENT

At Finse the effect of the Caledonian overthrusting on the Pre-Cambrian basement has been very slight. Thus *Torellella laevigata* has been perfectly preserved in shallow pockets in the basement.

South-westward from Finse the deformation increases gradually. South-east of Lofthus, about 50 km. from Finse, the quartz-schist has been folded and a fracture cleavage parallel to the plane of thrusting developed down to 500 m. below the thrust-plane.

Some 90 km. further south-west, in the Haugesund peninsula, there is complete conformity between the basement and the Cambro-Silurian schists. All structures in the basement seem to be of Caledonian age.

GEOMORPHOLOGY

The base of the Cambro-Silurian schists lies at an altitude of 1200–1400 m. in the western part of Hardangervidda. It marks a sub-Cambrian peneplain.

The present surface of the central parts of Hardangervidda approaches a peneplain, with hills reaching a height of 1300–1400 m. gently sloping down to broad valleys at 1100–1200 m. This peneplain nearly coincides with the sub-Cambrian plain, but it is of a much younger age, most likely Tertiary.

In late Tertiary times, probably Pliocene, the country was uplifted a few hundred metres, and steep-sided valleys were eroded from the coast inland. During the Pleistocene the glaciation immensely increased the erosion, but during interglacial times other eroding agents predominated. In many cases it is difficult to determine how much of the present surface-form belonged to the Tertiary peneplain, how much has been sculptured by ice, and how much is due to other eroding agents before, between and after the glaciations.

In the central part of Hardangervidda it seems that the effect of the glaciation on the form of the landscape has been slight. The mature character of the scenery has been preserved.

The contrast between the old surface and the young, steep-sided canyon is nowhere more striking than at Fosli. The upper part of the canyon exhibits no sign of being eroded by glaciers. On the other hand, the present river seems quite insufficient to produce a canyon several hundred metres wide. Reusch held that the upper part of the canyon was eroded by water falling through crevasses in the glacier and under it near the edge of the preglacial canyon. This part of the canyon should then have been formed like an enormous pothole.

B. The area west of the Hardangerfjord

While the sub-Cambrian peneplain in the north-western part of Hardangervidda lies at a fairly constant level of 1200–1400 m., it dips on the west side of the Hardangerfjord fairly steeply towards the north-west and disappears at Lussand below sea level.

In this locality the Cambro-Silurian schists are a few hundred metres thick and above them lies a large mass of overthrust rocks. These rocks have not yet been studied in detail north-west of Lussand–Fyksesund, but further west it is possible to distinguish between two overthrust masses or nappes. They will be referred to as the upper and lower overthrust masses. Geographically the upper mass lies east of the lower.

The dip of the strata changes towards the west from a north-westerly direction along the Hardangerfjord to a south-easterly 10–20 km. away from the fjord.

Below the schists at the base of the lower overthrust mass lies a complex of migmatites. Its tectonic position corresponds to that of the basement east of Lussand, but the rocks have been thoroughly deformed during the Caledonian orogeny, and there is a complete conformity between them and the overlying rocks.

The rocks between the Hardangerfjord and the Bergen Arcs may be divided into the following units:

5. The Upper Overthrust Mass, above 2*a*, 2*b*, and 2*c*.
4. The Lower Overthrust Mass, between 2*c* and 2*d*.
3. The Migmatites, north-west of and below 2*d*.
2. The Cambro-Silurian schists.
    - (*d*) Below and north-west of the overthrust masses.
    - (*c*) Between the overthrust masses, from Voss to Vaksdal.
    - (*b*) South-west of Fyksesund.
    - (*a*) Near Lussand.
1. The Pre-Cambrian basement.

1. THE PRE-CAMBRIAN BASEMENT

Between Kvandal and Lussand the basement rock is a rather massive granite. It contains several dark inclusions, some of which are probably metadacite, others metabasalt. Near the contact at Lussand the rock is gneissose, its foliation being parallel to the contact.

2. THE CAMBRO-SILURIAN SCHISTS

a. The schists from Lussand southward are mostly quartz-muscovite-biotite-schists, which at places are rich in graphite.

b. This area of schists comprises various sedimentary, volcanic and intrusive rocks, the stratigraphic sequence of which is not completely established.

The sedimentary rocks are mica-schist or phyllite, lime-silicate-schist, limestone, quartz-schist, and a polygenic conglomerate. The mica-schists are partly in the chlorite zone, partly in the biotite zone, partly in the garnet zone, and partly in the albite-porphyroblast zone. The lime-silicate schist contains quartz, albite, epidote and hornblende with or without garnet. The limestone is only a few metres thick, and no trace of fossils has been found. The conglomerate has cobbles of Caledonian volcanic and intrusive rocks in a groundmass rich in hornblende and chlorite.

The volcanic rocks are hornblende-schist and quartz-porphyry. The hornblende-schist is mostly an albite-hornblende-epidote-schist with or without chlorite and biotite. Oligoclase-hornblende-schists are rare, and so are albite-epidote-chlorite-schists. The quartz-porphyry has phenocrysts of microcline and albite in a groundmass of quartz, microcline, albite, muscovite and, occasionally, biotite. Part of the hornblende-schist and the quartz-porphyry may be sills, because the deformation lava flows and sills cannot always be distinguished.

The intrusive rocks are serpentine, gabbro, trondheimite, quartz-porphyrite and albite-granite. The serpentine consists mainly of antigorite, but olivine may be partly preserved. The gabbro is a saussurite-gabbro, containing green hornblende, albite or acid oligoclase, epidote and biotite. The trondheimite contains quartz, albite, epidote, biotite and muscovite, frequently also hornblende and garnet. The quartz-porphyrite has phenocrysts of albite in a groundmass of quartz, albite, epidote, biotite and muscovite. Two sills of albite granite are the youngest intrusives in the area. Contrary to all other rocks this latter shows no sign of mechanical deformation. Besides albite it contains quartz, muscovite, biotite and calcite.

Most of the rock types in this area also occur in the Major Bergen Arc of Cambro-Silurian schists.

c. Mica-schist or phyllite is completely dominating in this area. It is a quartz-biotite-muscovite-schist, in some places rich in graphite and locally containing garnets. A calcareous mica-schist occurs in part of the area, and small zones of limestone, hornblende-schist, quartz-porphyrite and trondheimite are found in a few places.

This zone of schists has been greatly deformed because of its position between two masses of overthrust rocks. Its present thickness decreases from several hundred metres in the north-east to only a few in the south-west, where it is discontinuous.

d. Two thin stripes of mica-schist (quartz-oligoclase-biotite-muscovite-schist) separate the lower overthrust mass from the migmatites below them, which have not been subjected to thrusting. These can be followed continuously from Vaksdal 55 km. north-eastward, until they join the main zone of Cambro-Silurian schists (*c*), in spite of their average thickness being less than 10 metres.

3. THE MIGMATITES

The migmatites consist of a granodioritic gneiss penetrated by thousands of dykes and veins of granite and containing a few minor bodies of amphibolite. In the upper, south-eastern part there is a gneissic hornblende-quartz-diorite. The age of the granite is most likely Caledonian; that of the other rocks is not known, but they may be Pre-Cambrian rocks which were thoroughly deformed during the Caledonian orogeny.

4. THE LOWER OVERTHRUST MASS

This name denotes a complex of rocks that have been thrust towards the east-south-east on the thin layers of mica-schist (2*d*) which separate it from the Migmatites. As there are two layers of mica-schist, running parallel at a distance of 0·5–1·5 km., the overthrust mass is actually split in two parts. These parts are here treated together.

In the table are shown the various rock-types occurring compared with those of the Telemark formation in Hardanger.

Lower Overthrust Mass	*Telemark Formation*	*Age*
Granite Younger quartz-diorite		Caledonian

Lower Overthrust Mass	*Telemark Formation*	*Age*
	Granite	Pre-Cambrian
Quartz-diorite	Quartz-diorite	
Saussurite-gabbro	Saussurite-gabbro	
	Soapstone	
Metarhyolite	Metarhyolite	
Metadacite	Metadacite	
Metabasalt	Metabasalt	
Tuffites	Tuffites	
Quartzite with quartz-schist and conglomerate	Quartzite with quartz-schist and conglomerate	

There is a striking similarity, not only in the above sequence but also in the individual rock types from the two areas. They are almost identical both in appearance and in mineralogical composition. The only exceptions are, first, that the soapstone and the granite surrounding the Telemark formation are not represented in the Lower Overthrust Mass, and, secondly, that the younger granite and quartz-diorite, which most likely are of Caledonian age, do not occur in the Pre-Cambrian of the Sörfjord area. It seems probable, therefore, that the rocks of the overthrust mass, with the exception of the granite and the younger quartz-diorite, belong to the Telemark formation and are of a Pre-Cambrian age.

5. THE UPPER OVERTHRUST MASS

This complex consists of the same rock types as the Lower Overthrust Mass but in a different metamorphic facies. In the Upper Overthrust Mass nearly all rocks are in the epidote-amphibolite-facies (albite and epidote), while in the Lower Overthrust Mass only granite and metarhyolite are in this facies, the other rocks being in the amphibolite facies (oligoclase-andesine without epidote) or in transitional stages towards the epidote-amphibolite facies (oligoclase-andesine and epidote).

C. Structure

That the overthrust masses have actually been thrust into their present positions is evident. This is borne out particularly by their relationship along the contact with the Cambro-Silurian schists in 2*b*. The schists have been compressed and folded near the contact; in one area they have been raised to a vertical position; in another they have been over-ridden by the overthrust rocks.

A detailed study of the various structural elements in the Bergsdalen quadrangle (which comprises most of the area west of Fykse-sund on the accompanying map) has led to interesting results regarding the relation of the trends of linear structures to the direction of movement.

Altogether seven different cases were distinguished.

1. On both sides of the thrust front the rocks have been folded along axes that are parallel to its local direction. With increasing

distance from the front the trend of the linear structures becomes independent of local irregularities in its direction.

2. During the overthrusting a lineation was formed parallel to the direction of movement both in the overthrust rocks and—less prominently and extensively—in the rocks compressed in front of and below the overthrust mass. In a section along the road from Norheimsund westward to Tysse, this lineation is exactly parallel in the Cambro-Silurian schists in front of and below the upper overthrust mass (2*b*), in the Upper Overthrust Mass (5), in the mica-schist between the overthrust masses (2*c*), and in the Lower Overthrust Mass (4). This parallelism proves that the lineation cannot be older than the thrusting. As the lineation in some places is folded along axes which are parallel to the thrust-front, it cannot be younger than the latest phase of the thrusting. Consequently it has been formed during the thrusting and parallel to the direction of thrusting.

The lineation is particularly prominent in the Lower Overthrust Mass, where, in one locality, the cobbles of a conglomerate have been elongated from five to ten times in the direction of the lineation. The cross-joints perpendicular to this lineation are also rather prominent, and several valleys and canyons have been eroded along them.

3. In the Upper Overthrust Mass south-west of Norheimsund the lineation changes gradually from east-south-east, which is the general direction of thrusting, to south-south-east. This deviation in trend has been interpreted as the result of a secondary movement of the overthrust mass, caused by a steepening of the thrust-front to a vertical position, whereby movement in a southerly direction afforded least resistance.

4. North-west of Norheimsund the main lineation in the Upper Overthrust Mass trends east-north-east, while, in the zones of actual thrusting in the same rocks, it trends east-south-east. There is no continuous change in trend of the lineation as in case 3, and there are no indications of movement in the direction east-north-east. It is concluded that the overthrust rocks in this area were stretched in the direction east-north-east while they were thrust in the direction east-south-east, because the larger rock masses to the north and the south were thrust in slightly divergent directions.

5. Near the larger plutons, which are assumed to have been more solid and more resistant to deformation than the surrounding rocks, the lineation changes its trend and tends to become parallel to the contacts of the pluton. In a conglomerate the same tendency was found in the trends of stretching of pebbles near a large, resistant boulder.

6. The Migmatites in the north-western part of the area have not been thrust, but they have been compressed in about the same direction as that in which the rocks at higher levels were thrust. They have achieved a lineation about perpendicular to the direction of compression, and they have been folded along axes that are parallel to the lineation.

7. In the Lower Overthrust Mass, the trend of the lineation changes gradually from north-east at the bottom to east-south-east at the top. This puzzling feature has been explained in the following way:

> The movement of the Lower Overthrust Mass began later than that of the Upper. While the Upper Mass was thrust, the uppermost part of the Lower was dragged along in the direction of thrusting, whereas the lowermost part was compressed in the same direction as the Migmatites below. Between these levels the rocks were partly dragged, partly compressed, the amount of dragging gradually decreasing from top to bottom. As a result of this complicated process the direction of least resistance, indicated by the trend of the lineation, also changed gradually from top to bottom. Later, during the thrusting, the Lower Overthrust Mass was separated from the Migmatites below and thrust into the Cambro-Silurian schists, the thin layers of mica-schist acting as lubrication for the movement. Evidence of this is seen in the fact that in, and immediately above, the layers of mica-schist, the lineation trends east-south-east, while everywhere else near the base of the Lower Overthrust Mass it trends north-east. The movement of both the overthrust masses must have proceeded simultaneously for some time, otherwise the perfect parallelism in lineation across the contacts will be difficult to understand.

As a general conclusion regarding the relation of trends of linear structures to the direction of movement in deformed rocks, the following statement can be given:

> In metamorphic rocks the lineation, which represents the direction of least resistance, may under certain conditions be formed at any angle with the principal direction of movement of the rocks.

This principle is the same as that which H. Cloos and his collaborators have found to be valid in plutonic rocks: the lineation, which represents the local direction of the maximum of elongation in the pluton, may form any angle with the main direction of propagation of the magma.

D. Geomorphology

The fjords and valleys of western Norway are excavated either along zones of less resistant rocks or along sets of joints. The main part of the Hardangerfjord is a ‘strike fjord’, which follows the contact between the Pre-Cambrian basement and the Cambro-Silurian schists. The Sørfjord is a typical ‘joint fjord’, eroded along north–south-striking joints. A typical ‘joint fjord’ is also the Fyksesund, a narrow, spectacular fjord with steep sides, which follows joints striking north-west and north-north-west.

Another geomorphological feature of scenic interest is the Tokagjel, a canyon connecting the valley of Steinsdalen west of Norheimsund, which is near sea level, with the Kvamskogen area 350–400 m. above sea level. The canyon is about 2·5 km. long and follows partly the strike of the Cambro-Silurian schists, partly joints about perpendicular to the strike.

In the Lower Overthrust Mass west of Tokagjel the prominent lineation trending between east and east-south-east and the cross-joints striking about north-south are both among the most characteristic features of the landscape.

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THE SILURIAN AND DEVONIAN ROCKS OF TURNER'S HILL AND GORNAL, SOUTH STAFFORDSHIRE

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CONTENTS

PAGE

1. INTRODUCTION 225
2. TOPOGRAPHY AND GENERAL STRUCTURE 226
3. STRATIGRAPHICAL SUCCESSION 227
   (a) Sedgley Limestone 227
   (b) Upper Ludlow Shales 228
   (c) Downton Castle Sandstone Group 230
      (i) Ludlow Bone Bed 230
      (ii) The Turner's Hill Beds 231
      (iii) The Gornal Sandstone 231
   (d) Temeside Beds 232
   (e) Red Downton Beds 233
4. THE STRATIGRAPHICAL POSITION OF THE GORNAL SANDSTONE 233

ACKNOWLEDGMENT 236

REFERENCES 236

SUMMARY.—The sandstone extensively quarried at Gornal, near Dudley, and known as the Gornal Sandstone, having yielded *Hemicyclaspis murchisoni* (Egerton), can no longer be regarded as part of the Coal Measures, and must be assigned to the Downtonian. From its lithological characters and stratigraphical relationships it seems probable that it should be correlated with the Downton Castle Sandstone Group of Elles and Slater, *i.e.*, with W. W. King's zone I.1. As a consequence the range of *Hemicyclaspis murchisoni* must be extended downwards.

With the help of this new evidence and numerous temporary exposures, the area of Turner's Hill and Gornal has been re-mapped and the structure re-interpreted.

An occurrence is recorded of lenticles of a bone-bed within the Sedgley (Aymestry) Limestone of Turner's Hill.

1. INTRODUCTION

THE area around Lower Gornal, some two miles north-west of Dudley, was surveyed by T. H. Whitehead for the Geological Survey during 1920–1 (Whitehead, T. H., 1920, 1921; Whitehead, T. H. and T. Eastwood, 1927; Whitehead, T. H. and R. W. Pocock, 1947), whilst Turner's Hill had earlier been investigated by W. W. King and W. J. Lewis (1912), and the same pair later (1917) mapped Ellowes Park to the north. The present re-mapping of the area in

1946–7, made at the suggestion of Professor L. J. Wills, was prompted by two factors:

(1) the discovery of a fine specimen of *Hemicyclaspis murchisoni* (Egerton) in the Gornal Sandstone (Wills, L. J., 1947, p. 71) which had hitherto been regarded as forming part of '. . . The great development of sandstones at or near the base of the Coal Measures . . .' (Whitehead, T. H. and T. Eastwood, 1927, p. 53.

(2) the development of a housing estate on Turner's Hill which provided numerous temporary exposures where none had previously existed.

Despite poor exposure and the complicated faulting, the re-mapping of the area, extending from Lower Gornal to the west side of Turner's Hill, has confirmed the following stratigraphical succession from above downwards (see Fig. 1):

Downtown Series

- (e) *Red Downton Beds*—Mainly purple, also some green, marls; micaceous siltstones and sandstones. Thickness, as estimated by King and Lewis (1917, p. 94) ... ... Up to 341ft.
- (d) *Temeside Beds*—Olive-buff shales and flaggy mudstones; with buff, grey, and green sandstones and occasional thin, impersistent bone-beds ... ... *ca.* 25ft.
- (c) *Downton Castle Sandstone Group.*
  - (iii) *Gornal Sandstone*—A yellow-buff, massive sandstone overlying
  - (ii) *Turner's Hill Beds*—A series of grey silty and carbonaceous shales above, and yellow-buff, silty sandstones, mudstones, and shales with thin, impersistent bone-beds below.
  - (i) *Ludlow Bone Bed* at the base.
    Estimated thickness of the whole group ... ... 70ft.

Ludlow Series

- (b) *Upper Ludlow Shales*—Grey, olive, buff, and brown shales, mudstones and flags, with grey nodular and flaggy, argillaceous limestones ... ... 30ft.
- (a) *Sedgley* (*Aymestry*) *Limestone*—Grey and blue nodular and flaggy, argillaceous limestones, with a thin and impersistent bone-bed near the top ... ... *ca.* 25ft.

2. TOPOGRAPHY AND GENERAL STRUCTURE

The outcrop of the Gornal Sandstone forms a well-marked NNE.–SSW. ridge, approximately one mile long with a maximum width of half a mile, merging northwards into the high ground of Sedgley. The western slope of the ridge sweeps steeply down to the level expanse of Ellowes Park which is located on the softer marls and sandstones of the Red Downton Beds. The southern slope of the Gornal Sandstone ridge is also steep, but the eastern slope is less so: both drop down to the surrounding undulating area of Coal Measures. It will be appreciated later that the topography of the Gornal ridge reflects its underlying anticlinal form, the steep western slope, however, being in part due to faulting.

To the south-west of the ridge, and separated from it by a shallow depression occupied by Red Downton Beds, is the prominence of Turner's Hill which resembles the Gornal Sandstone ridge in being elongated in a NNE.–SSW. direction, and in having a steep western and a gentle eastern slope. Turner's Hill is formed of rocks ranging upwards from the Sedgley Limestone to the Red Downton Beds, outcropping as an asymmetrical anticline which controls the topographic form of the hill.

North of Turner's Hill and to the west of the Gornal ridge is the level expanse of Ellowes Park, sited on Red Downton Beds which are folded into an anticline. The crest of the latter extends along the eastern margin of the park, whilst along the western border the beds become near vertical (King, W. W. and W. J. Lewis, 1912, pp. 91–4) as the Western Boundary Fault of the South Staffordshire coalfield is approached.

Thus there are three anticlinal areas, separated by faults. Two are composed of relatively resistant rocks and form hills, whilst the third forms level ground, although the rocks composing it are much more steeply folded.

3. STRATIGRAPHICAL SUCCESSION

The stratigraphical succession outlined in Section 1 is based on scattered evidence which will now be discussed in detail, from below upwards (see Figs. 1, 2, 3).

(a) Sedgley Limestone

The Sedgley Limestone has been accepted generally as being the Midland equivalent of the Aymestry Limestone of the Welsh Borderland; here, however, the local name is retained since a detailed correlation has not been attempted.

The Sedgley Limestone is exposed in two places at the foot of the western slope of Turner's Hill. The larger of these exposures is an old quarry (Whitehead, T. H., 1920, p. 11; Whitehead, T. H. and T. Eastwood, 1927, p. 14; Whitehead, T. H. and R. W. Pocock, 1947, p. 17), now almost completely overgrown and concealed by debris, except at the northernmost corner where a small part of the original face exists and shows blue-grey, dense, nodular, argillaceous limestone with thin shale partings, dipping at 15° to SW. The thickness of Sedgley limestone exposed in the quarry is approximately 25ft. Lower Ludlow Shales have been tentatively recorded by the Geological Survey from the base of the quarry.

Sedgley Limestone is now also exposed 50 yds. to the south of the quarry as the result of recent mining subsidence in the valley flanking the western slope of Turner's Hill. This exposure is some 20yds.

long and reaches a maximum height of 8ft. It shows nodular limestones like those of the quarry, but the beds at the top of the exposures are very argillaceous and flaggy, and contain *Serpulites longissimus*. It is probable that this small exposure represents the passage between the Sedgley Limestone group and the more muddy Upper Ludlow Series, but the actual transition is not visible owing to the thick cover of debris. The most interesting feature of this small exposure is an impersistent, thin bone-bed in the upper part, consisting largely of scales of *Thelodus* sp., black phosphatic grains and nodules and much shelly debris, with fragments of *Lingula* sp. and occasional *Onchus* sp.. The phosphatic grains vary in size from less than 1 to 15 mm., several having cores consisting of fragments of *Lingula* and in one case a complete dorsal valve of *L. lewisii*. The particular interest of this bed is that it is one of the lowest horizons from which ostracoderm remains have been recorded in England.

The bone-bed occurs as distinct patches filling in small hollows and depressions, as is demonstrated by one particularly well-preserved sample of sea-floor, a slab of limestone exhibiting an irregular surface covered with a 'sand' composed of shell debris and pink quartz grains, with some small limestone nodules (one crowned by a crinoid root), stromatoporoids, numerous brachiopods (especially rhynchonellids) and a pygidium of *Dalmanites vulgaris* (*caudatus*). The bone-bed material fills the bases of the deeper hollows, apparently drifted there by bottom currents. Moreover, the rounded nature of the scales of *Thelodus* and their close association with phosphatic grains and *Lingula* suggests transport by currents from probably more brackish zones: throughout there is much evidence of current-drifting of the bone-bed material. Other organic remains of great interest yielded by the bone-bed, are a number of conodonts which are at present being investigated by Dr. F. H. T. Rhodes.

The typical shallow-sea facies represented in the Sedgley Limestone suggests that land was not very distant. Further, an increase in the amount of silt is noticeable in the upper part of the limestone, and becomes conspicuous in the Upper Ludlow Beds which upwards become steadily more arenaceous and finally pass into the sandstones of the Downton Castle group. These changes appear to indicate that this neighbouring land mass was undergoing progressive uplift.

The fauna yielded by the limestone facies of the Sedgley Limestone includes: *Wilsonia wilsoni*, *Strophomena* cf. *rhomboidalis*, *Chonetes striatellus*, *Conchidium* sp., *Cardiola* cf. *interrupta*, *Bellerophon* cf. *aymestriensis*, *Pleurotonia* sp., *Orthoceras* sp., *Dalmanites vulgaris* and numerous other remains of brachiopods, crinoids, gasteropods, and stromatoporoids.

(b) Upper Ludlow Shales

These exhibit a wide variety of lithology from blue flaggy argillaceous limestones to olive-buff silty shales and sandstones, the shales

being the most common. Upper Ludlow rocks are exposed along the whole of the western foot of Turner's Hill north of the Sedgley Limestone outcrops, as the result of mining subsidence in the adjacent valley. The shales and limestones are often highly fossiliferous, both *Camarotoechia nucula* and *Chonetes striatellus* being common. It is impossible to sub-divide the series by means of these brachiopods as has been done in the type area (Ellis, G. J. and I. L.

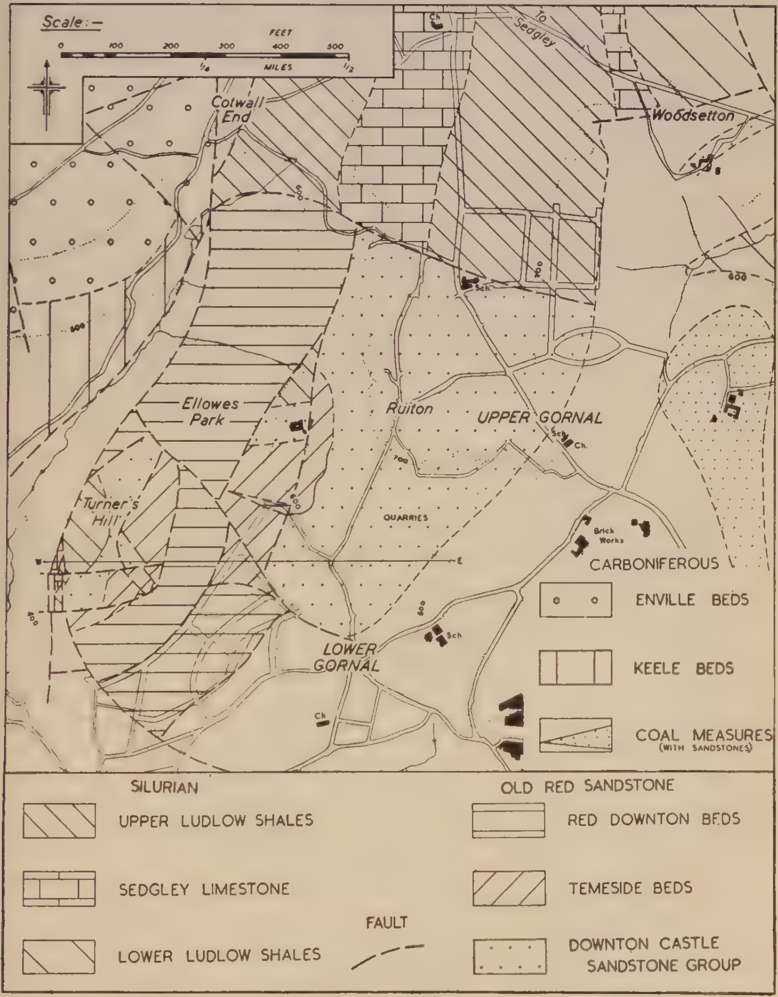

FIG. 2.—Geological map of Turner's Hill and Gornal.

Slater, 1906, p. 199), a conclusion also confirmed by the Geological Survey (Whitehead, T. H. and R. W. Pocock, 1947, p. 9). *Serpulites longissimus* occurs frequently in the calcareous facies. Where the shales, which often show signs of decalcification, become more muddy the fauna decreases and *Euomphalus carinatus* replaces the brachiopods.

In general, the Upper Ludlow Shales show an upward transition from argillaceous, flaggy limestones through olive-buff shales to buff, silty sandstones and mudstones at the top of the succession. The beds appear to dip at a low angle to the west and south-west along the foot of the hill,[1] whilst at the crest they were seen in a temporary excavation to become horizontal and then begin to dip with gradually increasing steepness to the south-east, revealing the anticlinal form of the hill. The total thickness of the Upper Ludlow Shales at Turner's Hill is in the region of 30ft.

Fragments of Upper Ludlow Shales have also been found to the north of Ellowes Hall confirming evidence obtained by the Geological Survey (Whitehead, T. H., 1921, p. 26; Whitehead, T. H. and T. Eastwood, 1927, p. 14; Whitehead, T. H. and R. W. Pocock, 1947, p. 17).

A hitherto unrecorded outcrop of calcareous shales, probably of Upper Ludlow age, has been discovered in the patch of waste ground enclosed by Valley, Tudor, Quarry and Glen Roads at Upper Gornal. This necessitates a modification of the Geological Survey 6-inch Sheet.

(c) Downton Castle Sandstone Group

(i) *Ludlow Bone Bed*

Excellently exposed at the crest of Turner's Hill, the rocks at the horizon of the Ludlow Bone Bed contain two principal 'bone-beds' with an intercalated lens of olive-buff shale. The lens thins out some 100 yds. to the east where the two bone-beds appear to have coalesced, forming a layer some 15 inches thick which outcrops between two faults The bone-bed contains a large amount of carbonaceous material and is as a whole very rotten and friable. The fauna includes *Lingula cornea*, *Thelodus* sp. (scales), *Onchus* and *Pachytheca*, the latter being preserved both in a carbonaceous and in a calcareous state. At Turner's Hill, at least, the Ludlow Bone Bed constitutes an excellent boundary between Silurian and Old Red Sandstone; for, though the beds above and below it are lithologically identical, their faunas are completely dissimilar, not a single representative of the Ludlovian fauna having been found above the Ludlow Bone Bed.

Thus the conclusions regarding the validity of the Ludlow Bone Bed being accepted as the Silurian–Old Red boundary, drawn by

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[1] It should be noted, however, that at one point Professor L. J. Wills has discovered signs of possible overfolding.

Dr. E. I. White (1950, pp. 58–65) from consideration of the major features, are closely supported by this minor, localised occurrence.

(ii) *The Turner's Hill Beds*

Immediately following the Ludlow Bone Bed at Turner's Hill are the buff, silty sandstones, mudstones and shales here termed the Turner's Hill Beds. As pointed out above these are lithologically identical with the Upper Ludlow beds immediately below the Ludlow Bone Bed, except for one important difference, namely the Turner's Hill Beds include thin impersistent parting of carbonaceous bone-bed, usually less than ½in. thick.

Intercalated with the sandstones and mudstones are lenticular beds of olive-buff shales yielding *Eurypterus* sp., including *E. pygmaeus*, *Pterygotus* sp., *Lingula* sp., including *L. cornea*, *Thelodus* sp., *Onchus*, and also large amounts of carbonised plant remains including *Cooksonia* sp. and *Pachytheca*, the latter also being preserved in a calcareous form. The full thickness of the Turner's Hill beds as exposed in the road section at the crest of Turner's Hill is 16ft. Here they are seen to be faulted against yellow-buff, flaggy sandstones of which a thickness of 10ft. outcrops. The latter show graded bedding and are so similar to the Gornal Sandstone of Gornal in general appearance and in heavy mineral content, that they are here regarded as part of that formation. It is the fault throwing them against the Turner's Hill Beds which prevents the highest beds of the latter group being seen here. These have, however, been exposed below the Gornal Sandstone to a depth of 7ft. in the quarries of Mr. Harper and Mr. Rollason at Lower Gornal and consist of dark-grey, carbonaceous shales and silty, micaceous shales, incorporating sandstone bands at Rollason's quarry. This group of shales and sandstones are reported by Messrs. Harper and Rollason to be some 10 to 12ft. thick, and to overlie buff-brown, hard, flaggy, calcareous sandstone, like some of the thin sandstones of the lower part of the Turner's Hill Beds.

The shales contain abundant macerated, carbonised (?) plant-remains and eurypterid fragments, including *Pterygotus* sp., *P. anglicus* and *Eurypterus* cf. *pygmaeus*. Thin 'coaly' layers (up to ¼in. thick) appear to consist of macerated fragments of eurypterid skins. The shales also contain *Lingula cornea*, *Thelodus* sp., *Onchus*, '*Ischnacanthus*', and a number of chitinous, spirally coiled (?) gasteropod remains, and fragments of a small undetermined lamellibranch.

(iii) *The Gornal Sandstone*

The Gornal Sandstone has been extensively quarried near Lower Gornal. It consists of 35ft. of yellow and olive-buff, massive sandstone, commonly exhibiting current-bedding and often graded bedding. The sandstone, which varies widely in degree of coarseness, is moderately well cemented by a muddy limonitic cement. Since it possesses a very low lime content the sandstone is now partly quarried as a refractory (Thomas, H. H., 1918, 1920; Whitehead, T. H. and R. W. Pocock, 1947, p. 181). Concentric iron-staining is common, as well as the development of veins of (?) limonite along joint-planes of which there are two major groups trending respectively NE.–SW. and NW.–SE., and a less well-marked one trending approximately N.–S. There appear to be three major 'partings' or bedding planes within the Gornal Sandstone, the surface of one showing ripple- and wave-markings as well as 'fucoid' markings and carbonaceous fragments. The alignment of the ripple-marking and false-bedding, though varying in detail, appear to suggest deposition from a north-easterly direction.

The sandstone has yielded to Mr. L. Rollason a headshield and a very fine and almost complete specimen of *Hemicyclaspis murchisoni* (Wills, L. J., 1947, p. 71, and 1948, pl. II). Professor Wills and the author have found in the basal 2ft. further fragments of *H. murchisoni*, several *Onchus* sp., *Pterygotus anglicus* and *Lingula* cf. *cornea*.[1] This fauna makes it obvious that the Gornal Sandstone does not constitute part of the Middle Coal Measures as has been thought hitherto (Whitehead, T. H. and T. Eastwood, 1927, p. 53; Whitehead, T. H. and R. W. Pocock, 1947, p. 37). The reasons for including it within the Downton Castle Sandstone Group are discussed below in greater detail, and, being accepted as such, this discovery of *H. murchisoni* extends its range downwards from King's Zone I 2 to Zone I 1 (Westoll, T. S., 1945, p. 355; White, E. I., 1950, pp. 54–5).

(d) Temeside Beds

At a point approximately 100 yards south-east of Ellowes Hall the top of the Gornal Sandstone is seen in an old quarry to be succeeded by olive-buff and grey, silty shales with bands of siltstone and muddy sandstones, with a thickness of 12ft. These shales have yielded *Onchus* sp., eurypterid fragments, *Lingula* cf. *cornea*, *Orbiculoidea* sp., and plant fragments, including *Pachytheca*, and are here accepted as constituting the base of the Temeside Beds (this acceptance of necessity being dependent on the Downton Castle Sandstone age of the Gornal Sandstone), thus forming an analogous sequence to that adopted by the Geological Survey for the Netherton anticline (Whitehead, T. H. and R. W. Pocock, 1947, pp. 17–20; see also Fig. 1). Some 70 yards west of the quarry Temeside Beds are again exposed and here they include thin impersistent lenses of 'bone-bed'.

At Turner's Hill the Temeside Beds consist principally of olive-buff shales lithologically identical with those of the Turner's Hill

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[1] In the Ludlow area the Downton Castle Sandstone and the Temeside Shales are characterised by *Lingula minima* and *L. cornea* respectively (Elles, G. L. and I. L. Slater, 1906), but at Gornal *L. cornea* appears to occur in both series.

Beds and yielding a similar fauna, including *Eurypterus* sp., *Sclerodus pustulifera* (Agassiz), *Onchus*, *Lingula* sp., and carbonised plant fragments including *Cooksonia* sp. and *Pachytheca*. Interbedded with the shales are occasional flaggy siltstones, whilst near the top of the sequence grey and green, hard sandstones appear. Owing to faulting, the thickness of the group cannot be directly determined, but it is estimated to be in the region of 25ft.

(e) **Red Downton Beds**

These beds are exposed in a stream draining westwards across Ellowes Park. This sequence has been fully described by King and Lewis (1917, pp. 92–4) and according to them reveals 341ft. of strata, principally purple marls with some purple and green micaceous sandstones (some of the red sandstones contain layers almost completely composed of mica flakes). The sandstones have yielded fragments of *Hemicyclaspis murchisoni* (Egerton) and *Didymaspis grindrodi* (Lankester) as well as *Onchus* sp. and *Lingula* sp. to King and Lewis who correlate the group with the Ledbury Passage Beds (King, W. W. and W. J. Lewis, 1917, p. 97; see also Whitehead, T. H. and T. Eastwood, 1927, p. 14, and Whitehead, T. H. and R. W. Pocock, 1947, p. 17).

The passage between the Red Downton Beds and the underlying Temeside Shales was revealed in a temporary excavation down the eastern flank of Turner's Hill. The green and grey, quartzose sandstone bands which occur in the upper part of the Temeside Beds were seen to persist into the base of the Red Downtonian, but die out rapidly. The Red Downton Beds of Turner's Hill are like those of Ellowes Park, consisting mainly of purple, micaceous marls and shales with bands of highly micaceous, purple siltstone and coarser green sandstone. The purple marls frequently contain irregular patches of green marl. The only fossils found were *Lingula* cf. *cornea* from the siltstone and sandstone bands.

It has been found impossible to correlate in detail the Red Downton Beds of Ellowes Park with those of Turner's Hill.

4. THE STRATIGRAPHICAL POSITION OF THE GORNAL SANDSTONE

Since the Gornal Sandstone can no longer be regarded as Carboniferous but must be recognised as Downtonian, the question of its position within that formation must now be discussed. Because *Hemicyclaspis murchisoni* is considered to be the index fossil of King's Zone I 2 (Westoll, T. S., 1945, p. 355)—in point of fact its range is imperfectly known, but nearly all recorded occurrences (see White, E. I., 1950, pp. 54–5) suggest Zone I 2—it would seem logical to place the Gornal Sandstone within the Ledbury Passage Beds and therefore in the same group as the Red Downton Beds of Ellowes Park and Turner's Hill. Nowhere, however, in the latter beds

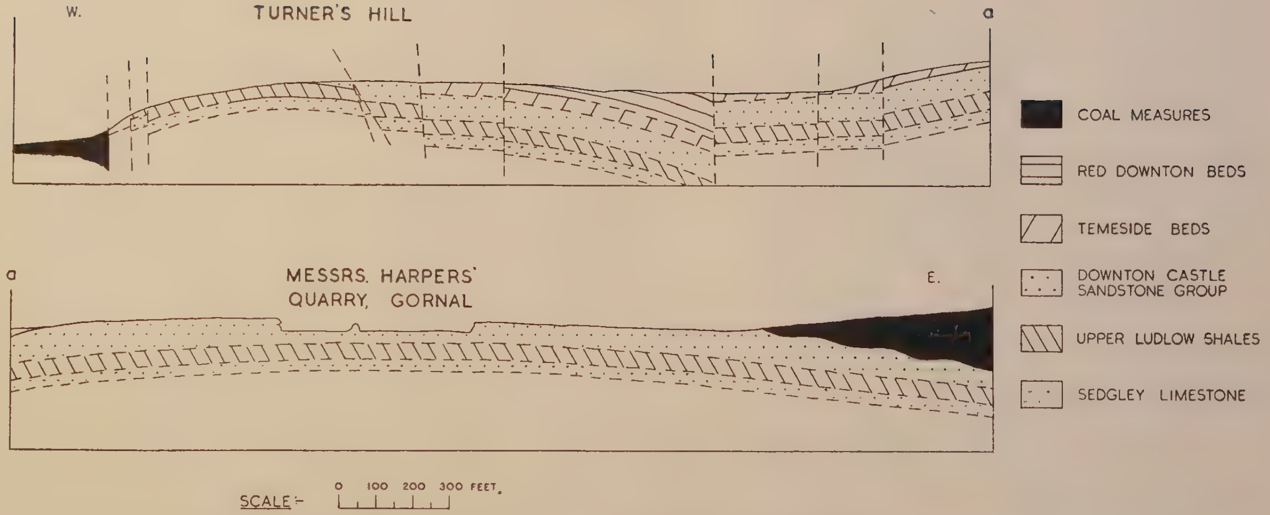

FIG. 3.—Section through Turner's Hill and Gornal. (The position of the line of section W–E. is shown on the map, Fig. 2, p. 229.)

as developed in this area, has a group of sandstones and shales comparable with the Gornal Sandstone been observed. On the other hand, there is a striking macroscopic similarity between the Gornal Sandstone of Gornal and the sandstone seen on Turner's Hill and here regarded as a faulted inlier of that rock (Fig. 3), and the heavy-mineral assemblages of the two rocks are very similar. Though the number of grains counted was relatively small (761 in the case of the Gornal Sandstone; 386 of the sandstone of Turner's Hill) the percentage of each mineral and the physical characteristics of the individual grains are so much alike that it seems justifiable to place them within the same group. The tabulated results of this count shows (*cf.* Fleet, W. F., 1925, pp. 104–6):

PERCENTAGE CONTENT OF MINERAL GRAINS

	Sandstone of Turner's Hill	Gornal Sandstone
	Turner's Hill	*Lower Gornal*
Zircon	42·2	49·1
Tourmaline	22·0	21·4
Apatite	20·1	14·9
Rutile	8·4	9·0
Anatase	7·1	5·3
	99·8	99·7

Further, as has been shown above, the Gornal Sandstone of Gornal is overlain by a group of shales and sandstones closely resembling the Temeside Beds of Turner's Hill in lithology, fauna and flora, and underlain by beds that resemble the Turner's Hill Beds.

Finally, there is a close resemblance between the succession in the Turner's Hill–Gornal area and that seen at Saltwells, Netherton, lying three miles to the south-east (Fig. 1), if the Gornal Sandstone be accepted as part of the Downton Castle Sandstone Group. The Netherton sequence has been described by King and Lewis (1912, pp. 437–43, 489–91), and revised in certain details by the Geological Survey (Whitehead, T. H. and T. Eastwood, 1927, pp. 15–17; Whitehead, T. H. and R. W. Pocock, 1947, pp. 17–20). The similarity of succession in the two areas is shown in Fig. 1, where it will be seen, however, that the Turner's Hill–Gornal sequence is incomplete owing to faulting.

A striking feature seen when the two successions (Fig. 1) are compared, is the close similarity in thickness of the Gornal Sandstone of Gornal and the Downton Castle Sandstone exposed at Netherton. In addition the two sandstones are lithologically alike. There is also a general similarity of faunas and lithology from the corresponding beds of the two successions, with the exception that relics of the Upper Ludlovian marine fauna persist into the Downton Castle Sandstones at Netherton.

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MYLONITISATION AND CATACLASIS IN ACIDIC DYKES IN THE INSCH (ABERDEENSHIRE) GABBRO AND ITS AUREOLE

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CONTENTS

	PAGE
1. INTRODUCTION	237
2. GEOLOGICAL SETTING	238
3. MYLONITISATION AND CATACLASIS OF ACIDIC INTRUSIONS	239
(a) Mylonitised Granite at Knockollochie	239
(b) Mylonitised Porphyrite at the Kennels of Westhall	242
(c) Cataclasis of Granite and Pegmatite in the Gabbro	243
4. DEFORMATION OF THE GABBROS	245
EXPLANATION OF PLATES	247
REFERENCES	247

ABSTRACT.—Along the southern margin of the Insch Gabbro, the gabbros and hornfelses, together with later dykes of granite, porphyrite and pegmatite, have undergone a dislocation-metamorphism with the production of mylonites, microbreccias and related cataclastic types. The selective reaction to stress is controlled by the nature of any particular rock and by its geological setting and associates. The dykes formed weak places in the edifice and cataclasis was concentrated along them. The significance of this new phase in the geological history of north-east Scotland is briefly discussed.

1. INTRODUCTION

ONE of the most important events in the geological history of north-east Scotland was recorded by the emplacement of half-a-dozen large and many small bodies of gabbro. This event can be dated as later than the regional metamorphism of the Highland Schists and earlier than the local Middle Old Red Sandstone. It may be called the Basic Phase of the 'newer granite' activity of the area, though it is becoming clear that 'newer granite' comprises a variety of rocks simply united at present by their post-dating the regional metamorphism. The manifestations of the Newer Basic Phase have been studied by W. R. Watt (1914, Huntly Mass), H. H. Read (1923b, 1924, Huntly Mass; 1923a, Arnage Masses; 1923b, Cabrach Mass; 1921, 1923b, Insch Mass; 1931, 1935, Haddo House Mass), M. S. Sadashivaiah (1950, Insch Mass), G. Whittle (1936, Insch Mass), and F. H. Stewart (1946, Belhelvie Mass). These masses are contained within Sheet 9 of the 4-miles to 1-inch Geological Survey map of Scotland, and a small map giving their distribution is provided by figure 11 of *British Regional Geology: The Grampian Highlands*, 2nd ed., 1948.

There still remains a great deal to be done before this igneous province is known in detail but, provisionally, its broad and patent provincial characters can be considered to be its overwhelming gabbroic nature, the noritic tendency of its gabbros, their proneness to contamination by country-rock material and their readiness to give troctolitic and peridotitic derivatives.

Among the larger bodies of Newer Basic material is the Insch Mass in which are developed some 80 square miles of noritic gabbros, troctolites and peridotites. The northern half of this mass was described by Read (1923b) and an eastern portion by Whittle (1936). Recently Read and Sadashivaiah have completed a survey of the whole of it, and this present communication gives an account of one of the many interesting results of this recent work. The Insch gabbros are invaded by a number of granite, pegmatite and porphyrite dykes which, in certain localities along the southern border of the mass, have undergone a dislocation-metamorphism with the production of mylonites, microbreccias and related cataclastic rocks. The hornfelses and gabbros that form the country-rocks of the mylonitised dykes have reacted to the stresses in ways that differ in kind or intensity from those shown by the dykes. One purpose of this paper is to study this selective reaction to dislocation-metamorphism displayed by the different rock-types. Further, the area dealt with in detail includes only a small part of the southern contact zone of the Insch Mass to which it forms an introduction. From the investigations of Read and Sadashivaiah it appears that this southern margin is characterised by a modification of the aureole, the presence of serpentine pods and a broad dislocation-metamorphism that may indicate a wide extension of the phenomena here described from the restricted area. When these investigations are completed it is possible that a significant but hitherto unrecognised episode in the geological history of north-east Scotland will be established.

2. GEOLOGICAL SETTING

The area here described lies between the villages of Oyne and Durno and its geology is shown in Fig. 1. The gabbro of the Insch Mass, here represented by dominant hypersthene-gabbro and less abundant olivine-norite, both modified to varying degrees, is in contact on the south with hornfelsed sedimentary schists, the position of which in the Highland Schist series is not yet established. Both the gabbro and the hornfelses are invaded by small bodies and narrow dykes of granite, pegmatite and porphyrite. Great parts of the rocks represented in Fig. 1, gabbros, hornfelses and acidic dykes alike, have been affected by cataclastic deformation. Very good mylonites are developed at two localities (M in Fig. 1): west of Knockollochie where a granite dyke in hornfels is involved, and at the Kennels of Westhall where a porphyrite dyke shows mylonitised margins against gabbro. It will be convenient to describe the mylonitisation and cataclasis undergone by the acidic dykes and their country-rocks first and then to deal briefly with the possible modifications of the gabbro.

3. MYLONITISATION AND CATACLASIS OF ACIDIC INTRUSIONS

The mylonites are of much geological and petrogenetic interest and accordingly their consideration comes first and is followed by an account of the cataclasis suffered by granitic intrusions in general. As has been mentioned, mylonites occur at two localities, one in the aureole, the other in the gabbro—at both, acidic dykes are involved.

(a) **Mylonitised Granite at Knockollochie.** In a small copse in the north-western corner of the first field west of the farm of Knockollochie, there are found abundant outcrops of hornfelses. These are mostly compact fine-grained blue-black rocks, often garnetiferous. Across the outcrop runs a banded black and white rock, the mylonite, 6in. thick, striking east-north-east–west-south-west, and dipping at 45° to the north-north-west.

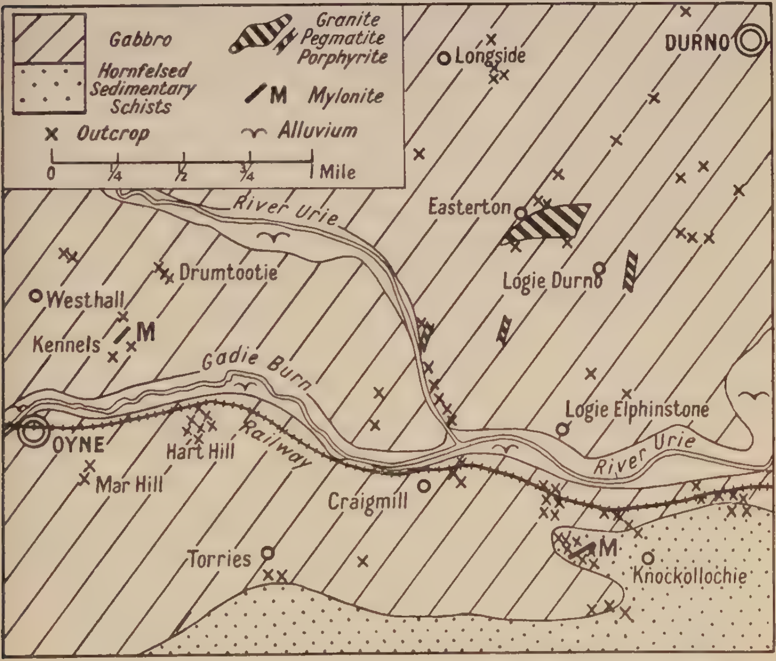


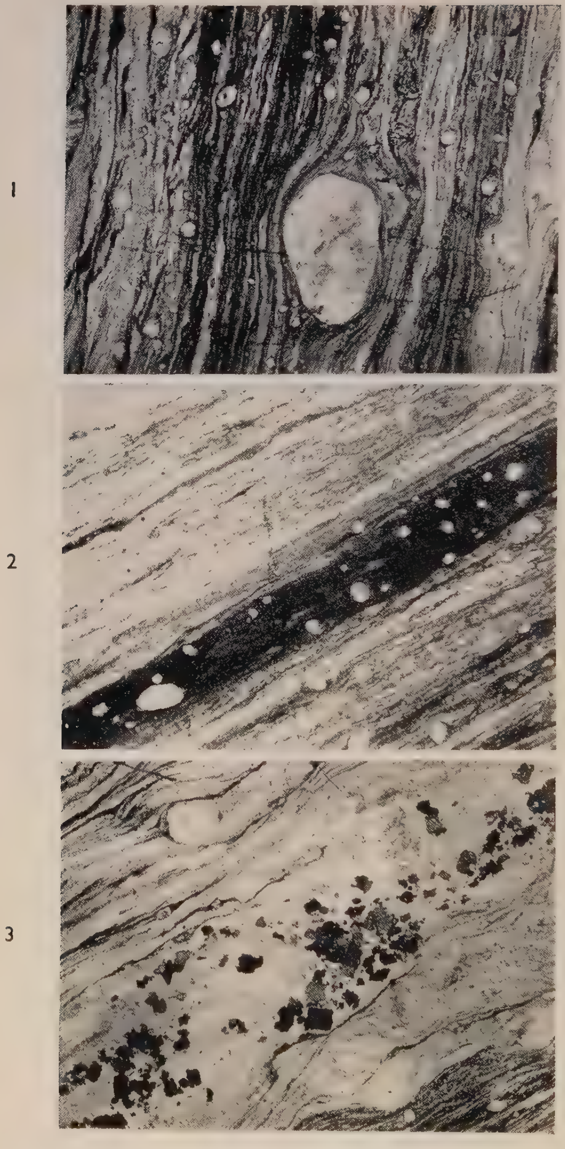
FIG. 1.—Portion of the southern margin of the Insch Igneous Mass, Aberdeenshire.

In hand-specimen, the mylonite is striped black and white. The black bands reach a thickness of 1½in. but are usually much thinner and often appear as inconstant wisps. They look like flinty-crush rocks and, equally, like dense hornfels, but they often show in them tiny round blebs of felspar. The white bands, clearly of granitic origin, are made of a dense dull groundmass in which appear shining facets of felspar. Both kinds of bands show a streaky or platy structure parallel to which the mylonite splits.

In thin section, the white bands are seen to be mylonites obviously derived from a coarse granite. In certain stripes showing the beginning of the transformation, the texture of the granite is partly preserved (Plate 9, Fig. 1). The original rock consisted of a coarse association of orthoclase, less abundant acid plagioclase, quartz and yellow to brown-red biotite, with the usual granitic texture. Now the orthoclase shows a hazy pressure twinning, the plagioclase has a zoned margin possibly induced by stress, the biotite flakes are bent and frayed out. The large original grains of quartz are either intensely strained or have broken down into tiny granules with intricately crenulated borders against one another; in places the quartz has begun to flow in curving streaks between the felspar grains. It is noticed that mica flakes and quartz drops enclosed in felspar are completely unstrained. These early stages of mylonitisation are thus characterised by porphyroclasts of the original minerals set in a mortar of quartz, felspar and biotite; the rocks are microbrecciated granites.

By the increase of granulation and the development of a flow-texture in the microbrecciated types, there are produced white bands of granitic mylonite which show porphyroclasts of felspar in an extremely fine-grained groundmass. The porphyroclasts are lensed, oval or almost circular in cross-section. Often it is clear that a string of felspar pills has been developed from a large original individual. The orthoclase is strained and may show an undulose extinction parallel to the margin of the porphyroclast; there is usually a good development of microclinic twinning even when the orthoclase encloses unstrained quartz and plagioclase. Plagioclase porphyroclasts also give an undulose extinction parallel to their present margins and their twin-lamellae are often faulted and displaced. Occasionally, however, the felspars may preserve their original crystal-shape to a marked degree, the fine quartz groundmass having flowed past crystal-edges without injuring them. The groundmass of these granitic mylonites is made of tiny quartz grains, usually in thin streaks, arranged in a flow-pattern picked out by films of minute biotite flakes and iron-ore dust. The normally even flow-pattern often becomes turbulent by swirling around large porphyroclasts that are set obliquely to the main flow-direction.

Tourmaline is common in many of the granitic mylonite bands. It occurs in tiny irregular fragments, obviously derived from larger



Photomicrographs of Mylonites, Insch Aberdeenshire.

[*To face page* 241.

crystals, spread out in a flow-lens (Plate 8, Fig. 3). One such lens shows nearly a couple of hundred fragments of tourmaline dispersed over a stretch of nearly an inch. These vary in body colour from pale lavender to deep blue-green and are therefore disoriented chips.

The bands of white granitic mylonite pass with a more or less rapid transition to the black bands. Occasionally the presence of many felspar porphyroclasts in the marginal parts of the black bands provides a sort of transition between the two; at other times, the bands are quite sharply separable.

The black bands owe their colour to their richness in tiny biotite flakes and iron-ore dust. They show in thin section a delicate ribbon-fabric of quartz, biotite, iron-ore and felspar, disturbed by porphyroclasts of felspar and garnet, and further interrupted by thin inconstant lenses of coarse quartzo-felspathic material (Plate 8, Fig. 1). The amounts of biotite and iron-ore, and consequently the depth of colour, vary in narrow bands. Garnet occurs sporadically throughout the laminae (Plate 8, Fig. 2). It forms colourless grains, sometimes apparently broken and lensed but occasionally possessing excellent crystal form. Epidote occurs as tiny augen in some bands poorer in biotite. The discussion of the origin of the black mylonite bands may conveniently be deferred till the associated hornfelses at Knockollochie are described.

These hornfelses are mostly of argillaceous composition but some bands are derived from impure calcareous sediments. The common types are composed of various assemblages of quartz, cordierite, acid plagioclase, red biotite, euhedral or subhedral garnet and hypersthene; occasionally large plagioclase porphyroblasts are present. Some of the hornfelses found in close association with the mylonite band are completely undisturbed. For example, one rock is a granoblastic aggregate of unstrained quartz, fresh cordierite and plagioclase in which are spongy garnets and delicately ramifying biotites that show no signs of deformation. In other hornfelses still only slightly affected by dislocation, the quartz has a weakly undulose extinction and the plagioclase twin lamellae are sometimes gently bent; in slices of such rocks there are usually present two or three parallel planes of fracture or incipient shear that have afforded channels for the deposition of minute sericitic or chloritic aggregates. A more advanced stage is marked by the breaking-down of the strained quartz into a multitude of tiny unstrained grains with crenulate margins. This process may continue till rather extensive lenses of granulated material are formed. These sweep around garnet sponges which enclose unstrained quartz and biotite. In such rocks, biotite has become shredded out into smaller wisps. It should be noted that cordierite is unchanged. Impure calcareous bands amongst these hornfelses are represented by quartz-epidote rocks in which the quartz is intensely granulated.

It is now seen that the hornfelses associated with the mylonite band are either completely unaffected by any cataclastic transformation or show only early stages of reaction. In the most advanced stage of deformation, there appear lenses which are not entirely unlike certain of the black bands of the mylonite, but such lenses are coarser in grain and less ribboned than those of the mylonite, and quartz and biotite are less thoroughly mixed in them. It must be concluded that the mylonite was formed on a weak band of granite in the tougher hornfelses. We have a special case of the old problem of deformed dykes in undeformed country-rocks.

The origin of the black bands in the mylonite may now be considered. The abundance of micaceous material in them and their richness in garnet suggest that they are primarily derived from the hornfelses. The felspar porphyroclasts in them might come either from the porphyroblastic felspars of the hornfelses or, much more likely, from the granitic dyke. It is true that the garnet in the black mylonite is often euhedral and might be interpreted as produced during the movement or later. It is preferable, however, to regard the garnets as porphyroclastic relics; it is hoped that the question may be further explored by detailed mineralogical work on the garnets of the black mylonites and the hornfelses.

It is concluded, therefore, that the ribboned black and white mylonite (Plate 8, Fig. 2) is due to the tectonic mixing of granitic and hornfels material, the operation being localised by the presence of the weak granite dyke in the tough aureole rocks.

Hornfelses similar to those of the Knockollochie mylonite locality are exposed in the railway-cutting to the north-east. Examination shows that they have undergone a low and variable degree of cataclastic modification. Blue argillaceous hornfelses, composed of cordierite, biotite, plagioclase, garnet and either spinel or quartz, are unaffected. On the other hand, siliceous hornfelses are found to have their quartz badly strained and in places granulated, except where protected within garnet sponges; delicate felspar lamellae are undisturbed.

(b) **Mylonitised Porphyrite at the Kennels of Westhall.** A third of a mile south-east of Westhall a tree-clad rock-knoll rises from the cultivated fields. Gabbros in various stages of modification form most of the knoll, but a couple of porphyrite dykes with mylonitised edges against brecciated gabbro provide the immediate and greater interest. These dykes run north-east from the ruined kennels on the west side of the knoll and have been quarried throughout their lengths, so that not much more than their contacts with the gabbro is now visible. There appear to be two dykes because the quarry holes are not quite on the same strike or, alternatively, one dyke may be shifted by faulting. The dykes are about 10ft. in width and their walls dip steeply to the south-east.

The rock of the dyke is a whitish grey porphyrite. In slice, it is seen to be composed of large euhedra of acid plagioclase and darker phenocrysts, possibly originally of hornblende but now replaced by chlorite, epidote, carbonate and ore, set in a fine-grained groundmass of felspar and decomposed mafic materials. When this porphyrite is traced towards the contact with gabbro, it is seen to be streaked out into a mylonite of plagioclase porphyroclasts set in a base of comminuted material striped with narrow darker wisps of epidote, chlorite, iron-ore and possibly mica (Plate 9, Fig. 3). The contact with the gabbro is rather wavy. At the contact, the gabbro is a streaky microbreccia of hornblende laths, plagioclase and ore, with porphyroclasts of amphibole (Plate 9, Fig. 3). Further from the contact, the gabbro is amphibolitised and brecciated. The original pyroxene has been converted into composite aggregates of pale yellowish-green amphibole, the plagioclase is broken and faulted; abundant iron-ore forms lenses and trails and the whole is traversed by narrow belts of microbreccia. In certain patches, the original texture of the gabbro is preserved, but the pyroxenes are uralitised and the felspars are traversed by a network of cracks outlined by chloritic substance. In one slice, a few large biotites, not particularly disturbed and of uncertain origin, lie parallel to the contact.

The gabbros exposed elsewhere on the Kennels knoll are coarse rocks composed of labradorite and pyroxene, and are in some parts not much modified. In others, however, the pyroxenes have been replaced by hornblende with the separation of much iron-ore, and the rocks are traversed by shear- and breccia-belts in which chlorite and epidote are developed. Anorthositic bands show their labradorite plates to have bent and broken twin lamellae, and their original scanty pyroxenes to be replaced by epidote and chlorite which also occur along shear-planes. Apart perhaps from the microbreccia belts, these are types widely developed elsewhere in the gabbro of the area and their discussion may conveniently be postponed to a later page.

The reaction to dislocation-metamorphism of the rocks at the Kennels of Westhall differs from that at Knockollochie. At Westhall, the gabbro has failed by microbrecciation, whereas the porphyrite is unaffected except for a narrow mylonite selvage at the contacts. At Knockollochie, the granite dyke was the weak part of the edifice and movement on it produced banded mylonites by the tectonic incorporation of hornfels material, but the adjacent hornfelses were only moderately affected, if at all.

(c) **Cataclasis of Granite and Pegmatite in the Gabbro.** Four small intrusions of acidic rocks occur in the eastern part of the gabbro area between the River Urie and Durno (see Fig. 1). Three of these are dykes of pegmatite, the fourth is a small body of microgranite.

The microgranite at Easterton is a fine-grained pinkish rock, breaking irregularly. In slice, it is seen to have been profoundly modified by cataclasis. Porphyroclasts of 'microclinic' orthoclase and less abundant acid plagioclase are set in a fine granular aggregate of quartz which flows around the felspar fragments. Biotite flakes, partly bleached or chloritised, are bent, shredded out or streaked into wavy films. The rock is a granitic microbreccia. The gabbros associated with the microgranite provide a marked contrast in that they show no cataclastic effects apart possibly from very rare belts of veining. Thus, a slice of an olivine-norite shows one such vein-belt made up of narrow veinlets filled with chlorite plates, and another of a hypersthene-gabbro is traversed by a single vein of chlorite and carbonate adjacent to which the original pyroxenes are converted into aggregates of amphibole fibres; whether this veining is to be ascribed to deformation is discussed below.

The pegmatites form dykes up to 35 feet in width and are very coarse muscovite-tourmaline-pegmatites, composed of quartz, potash-felspar, acid plagioclase, muscovite and tourmaline. In slice, evidences of deformation are provided by the bending and faulting of felspar lamellae, and by the cracking, straining, and granulation of the quartz which often passes into stripes of finely crenulated grains along certain narrow belts (Plate 9, Fig. 2). In some rocks, the potash-felspar is traversed by a set of parallel planes lined with tiny sericite flakes and occasionally another set of fracture planes is healed by quartz. In patches, a felspar microbreccia is produced. Some of the gabbros exposed near the pegmatites show no signs of cataclastic modification but others are markedly changed in ways similar to those described and discussed later from the gabbros in general; veining, microbrecciation and amphibolitisation are sporadically well developed.

The quartz of the deformed pegmatites shows innumerable planes of liquid inclusions that traverse many contiguous quartz grains (Plate 9, Fig. 2). These planes are in roughly parallel sets, occasionally crossing one another, and their orientation appears to be related to planes of obvious fracture. Their presence, in abundance, in these deformed rocks is of interest in view of the recent work of O. F. Tuttle (1949). From a detailed petrofabric study of such planes in the granitic rocks of Washington, D.C., Tuttle suggested that they 'originated as fractures in the quartz grains, which subsequently became filled with solution. The solution-filled fracture is believed to change to numerous individual inclusions by a process of solution and deposition of silica' (*loc. cit.*, p. 354). The planes were found to have a uniform orientation over an area of 15 by 20 miles in the Washington district, but no macroscopic structures could be found that were genetically related to them. In view of the occurrences of well-developed planes of liquid inclusions in the Insch deformed pegmatites, it is evident that a detailed study, especially of oriented specimens, will throw light upon their time and genetic relations to the macroscopic movement-planes of the dislocation-area.

4. DEFORMATION OF THE GABBROS

In earlier pages it has been incidentally noted that there are certain characters of the gabbros of this special area that must be ascribed to the cataclastic deformation—such characters are microbrecciation (Plate 9, Fig. 4) and deformation of felspars. Whether the veining repeatedly observed and the widespread amphibolitisation that is closely associated with it are also to be related to the same deformation-process, is a matter for discussion. This is particularly the case because similar rocks in the 'newer' gabbro masses of north-east Scotland have been considered by Read (1935), Whittle (1936) and Stewart (1946) to be due to end-stage modification of primary igneous minerals during the final episode of magmatic consolidation. This important question can be dealt with here only in an interim fashion since similar phenomena are probably well developed all along the southern border of the great Insch gabbro body. All that is done on this present occasion is to outline the problem in the hope that detailed work along the whole contact will eventually provide a solution.

The unmodified gabbros of the Insch Mass have been described by Read (1923) and Whittle (1936). They are beautifully fresh rocks made of labradorite and pyroxene with olivine in some varieties and a little biotite in most. Such gabbros, scarcely modified, occur within the area dealt with in this paper. They have been mentioned already from the localities of microgranite and pegmatite, and additional examples of such almost unaltered types are found between Logie Durno and Durno, and in the valley of the Urie near the mouth of the Gadie Burn. These rocks are, however, traversed by a few chloritic vein-belts—whether this is an early phase of end-stage alteration or of deformation-metamorphism is the subject for later consideration.

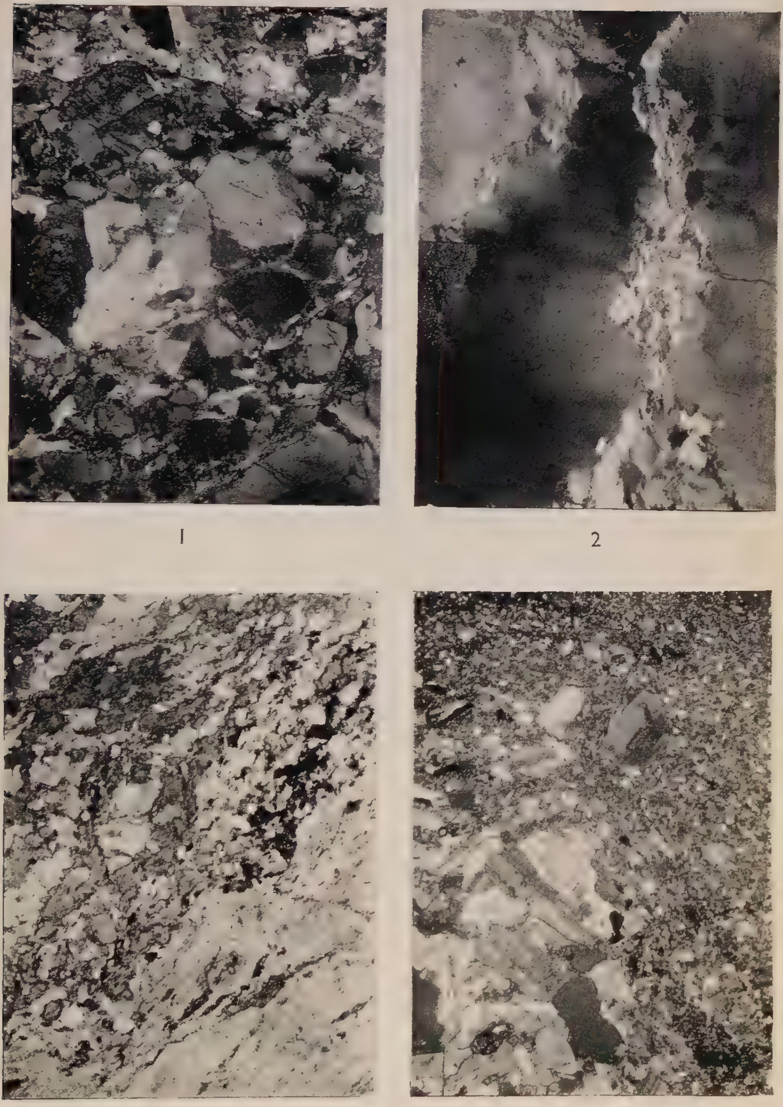
It is certain that the gabbros have in many places undergone microbrecciation and shearing (Plate 9, Figs. 3 and 4); examples come from the Kennels of Westhall, from Hart Hill and from the southern margin of the gabbro body north of Knockollochie. The rock from Westhall, for instance, is seen in slice to retain its original labradorite and pyroxene unchanged, except along narrow belts of brecciation where the labrodorite is broken up into fragments and the pyroxene converted into an aggregate of pale amphibole fibres. In other examples, the felspar is lensed, fractured, bent and strained, and is often cloudy with sericite. Chlorite veins are common in these rocks. Such modifications can reasonably be connected with the dislocation-process.

We now return to the consideration of the almost unmodified gabbros traversed by vein-belts. These rocks show practically no brecciation or discrete cataclasis, but the parallelism of the veins, and the slight shifts of felspar lamellae on them and the ease with which they cut through the original minerals, including iron-ore, indicate that they occupy fractures. It is again reasonable to relate this fracturing to the general dislocation-process. In the vein-belts and adjacent to separate veinlets, the pyroxenes of the original gabbros are converted into aggregates of bladed amphibole with the separation of much iron-ore. Occasionally these amphibole aggregates have their rims of a deeper greenish-blue colour. It is clear that this amphibolitisation is likewise a consequence of the deformation-metamorphism.

Over much of the special area studied, the gabbros have been converted into dense green rocks in which amphibolitisation, of the type associated with the veining described above, has affected the whole of the rock. Sliced specimens come from the Urie north of the Gadie junction, along the southern margin north of Knockollochie and near Durno. They show a coarse association of saussuritised and sericitised labradorite and aggregates of bladed amphibole with much iron-ore, these aggregates commonly having deeper-coloured margins. The original texture is largely preserved though the amphibole substance has moved in places into the felspar areas. Evidence of cataclasis is provided by undulose extinction of the felspars and by bending and faulting of their twin lamellae.

It would be possible to interpret this thorough amphibolitisation of the gabbros as an extension of the changes seen along the vein-channels and therefore due to the post-granite deformation but, as already mentioned, exactly similar rocks have been considered by Read, Whittle and Stewart to result from end-stage action. It is possible that such rocks may arise by more than one process. It may be recalled, however, that in the detailed description of similar rocks ascribed to end-stage action from the Belhelvie Mass given by Stewart (1946), mention is repeatedly made of deformation-phenomena. Thus, 'at Belhelvie Quarry, Hassock's Croft, and several other places the rocks show evidences of dynamic metamorphism—cataclastic structures and pronounced schistosity', and, 'hypersthene-gabbros have all been considerably modified by end-stage action, and commonly by shearing' (*op. cit.*, p. 477). Further, 'the end-stage rocks in several places . . . have been subjected to shearing. In these types the felspars show strain-shadows, and are often bent and shattered. Mortar structure is common' (*op. cit.*, p. 479). Stewart (*op. cit.*, pp. 477, 482) states that granitic dykes have been intruded along the shear-zones—an observation potentially of fundamental significance.

Which of the two possibilities, end-stage action or dislocation-metamorphism, is best suited for the rocks of any particular area of the Insch Mass may be decided when the detailed study by Read and Sadashivaiah of the southern margin of it is completed. In the special area described here, there is evidence that between the crystallisation



1 2

3 4

Photomicrographs of cataclastically deformed rocks, Aberdeenshire.

[*To face p.* 246.

of the gabbro and the formation of some amphibole, there was a period of dyke-intrusion by acid magmas.

EXPLANATION OF PLATES

PLATE 8.—*Photomicrographs of Mylonites, Knockollochie, Insch, Aberdeenshire.*

Fig. 1. Porphyroclasts of felspar in a ribboned mylonitic base. Ord. light, X 20.

2. Banded black and white mylonite with many small garnets in the black band. Ord. light, X 20.

3. Spreading-out of tourmaline fragments (dark) in a mylonite streak. Ord. light, X 20.

PLATE 9.—*Photomicrographs of cataclastically deformed granite, pegmatite, porphyrite and gabbro, Insch Mass, Aberdeenshire.*

Fig. 1. Mortared granite, Knockollochie. Early stage of mylonitisation shown by large porphyroclasts of felspar and quartz in a fine-grained base of granulated quartz. Crossed nicols, X 20.

2. Sheared pegmatite, east of Logie Durno. A shear-zone marked by tiny quartz grains traverses large strained original quartz grains showing undulose extinction. Planes of liquid inclusions can be seen to the right of the granulated band and running slightly obliquely to it. Crossed nicols, X 20.

3. Mylonitised contact of porphyrite (lower right) and gabbro (upper left), Kennels, Westhall. Streaking-out of the porphyrite and microbrecciation of the gabbro adjacent to the contact. Ord. light, X 20.

4. Microbrecciated contact of porphyrite (right) and gabbro (left), Kennels, Westhall. Portions of the gabbro are broken down into a microbreccia. Crossed nicols, X 20.

Note.—Photomicrographs of Plates 8 and 9 by Mr. J. A. Gee, Imperial College.

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HOWCHINIA BRADYANA (HOWCHIN) AND ITS DISTRIBUTION IN THE LOWER CARBONIFEROUS OF ENGLAND

By A. G. DAVIS, F.G.S.

[*Received* 8 *March* 1951]

CONTENTS

	PAGE
1. Introduction	248
2. Systematics	248
3. Particulars of Localities	250
Acknowledgments	252
Explanation of Plates	253
References	253

SUMMARY.—The foraminifer *Howchinia bradyana* (Howchin) is re-described and re-figured and a lectotype chosen. Previously only known from the type locality, its distribution is now extended to the midland provinces. Its stratigraphical range has been determined with more certainty than hitherto.

1. INTRODUCTION

In the course of the D'Arcy Exploration Company's exploratory drilling in the Lower Carboniferous of the northern and midland counties of England the utility of foraminiferal controls was instanced by the re-discovery of *Howchinia bradyana* (Howchin). The recognition of a comparatively short ranged form as an indicator of the proximity of D limestones at depth became an important factor both in attaining operational objectives and also in correlation. *Howchinia bradyana* was discovered in 1873 by the Rev. Walter Howchin in the limestone outcrops of Cowburn and Tipalt in Northumberland and was not again encountered until 1941 when the writer recognised it in cores from No. 1 boring at Cleveland Hills, Yorkshire. Exploratory drilling during the years 1941–8 has yielded a considerable amount of information regarding the distribution of this species and it is now known that it makes its earliest appearance in the highest D limestones and ranges upwards to the limestone facies of P_{1d}. Its acme is probably in B_2–P_{1a} where it is sufficiently abundant to be recovered and recognised in rotary cuttings.

Northumberland still remains the most northern geographical occurrence while its southern limit is, at depth, in Nottinghamshire.

2. SYSTEMATICS

Genus: **HOWCHINIA** Cushman, 1927

Genotype *Patellina bradyana* Howchin, 1888. Monotypic. Lower Carboniferous. England.

Howchinia bradyana (Howchin)

Plates 10 and 11

Patellina bradyana Howchin, 1888, p. 544, pl. IX, figs. 22–5.

Howchinia bradyana (Howchin) Cushman, 1927, p. 42, pl. 6, figs. 4a–b (reproduced from Howchin 1888); 1928, p. 179, pl. 23, figs. 1–4; 1933, p. 174, pl. 19, figs. 18–9.

Howchinia bradyana (Howchin) Galloway, 1933, pp. 88–9, pl. 7, figs. 8a–b (reproduced from Howchin 1888).

Howchinia bradyana (Howchin) Cushman, 1940, p. 193, pl. 19, figs. 18–9.

Howchinia bradyana (Howchin) Davis, 1945, table facing p. 314.

Howchinia bradyana (Howchin) Cushman, 1948, p. 210, pl. 19, figs. 18–9.

Lectotype: The type and original figured specimens have not been traced, but in H. B. Brady's collections, preserved in the British Museum (Natural History), is a set of ten topotypes from Northumberland. P.40403[1] is here selected as lectotype.

Topotypes: P.31895, P.40342 and P.36616, the latter consisting of seven examples mounted on a single slide. The writer is indebted to Mr. C. D. Ovey for permission to prepare sections of topotypes P.31895 and P.40342.

Howchin's original description is as follows:

> Test free; conical; trochoid; primordial end obtusely pointed; transverse section circular; length equal to two or three times the diameter of the test; inferior side slightly concave; external surface limbate; exhibiting numerous annular, semi-annular, or spiral whorls of raised shell-substance alternating with lines of depression; depressed areas bridged by minute crenulations of the test, which, as raised transverse lines, connect the limbate septal ridges. Internal structure a simple, undivided and continuous spiral chamber (or alternating semi-annular chambers?). Chamber cavity compressed. Umbilical region extending almost the entire length of the shell and of nearly equal diameter throughout, filled with uniform shell substance. Convolutions of spire varying from five to twelve; average number ten. Aperture a narrow slit, extending from the periphery to the umbilical margin. Umbilicus depressed; or frequently, marked by a raised lip extending from the umbilical termination of the orifice, forming a low semi-circular wall defining the central portions of the test. Length about 1/38 in.; diameter, at base, 1/100 in.

After an examination of the type material and many examples in thin rock sections from a number of new localities, it may be said that Howchin's careful description still stands and only needs slight revision. The test is trochoid and consists of a spiral tube wound round a conical umbilical core of microcrystalline shell structure. The spiral tube shows in some instances traces of a septum and Howchin's suggestion that the tube might form alternating semi-annular chambers, is probably correct. These septa may be traces of growth stages or the laying down of calcium carbonate. The original figures, showing the external features, on comparison with the type material, suggest that the crenulation or pitting of the test is an exaggeration of the artist. Subsequent reproductions of Howchin's figures (by Cushman and Galloway) have suffered so much from re-touching that a fresh series of figures is required.

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[1] Registered numbers prefixed by P. refer to specimens preserved in the British Museum (Natural History); other registrations refer to the Geological Survey Museum, London.

The structure of the shell wall is minutely granular as in *Endothyra* and *Fusulina* as described by Wood (1949, p. 238). The whorls are marked out on the exterior by zonal bands of lighter or darker shading. The umbilical plug or core is often coarsely crystalline and differs from the wall structure and the surrounding matrix. The varying degrees of grain structure may be due to re-crystallisation.

Measurements. Average full-grown individuals:—

Height 0·6 mm. Diameter at base 0·25 mm.

Examples are often found which have only attained less than the first two whorls (Richmond, Yorks.).

Remarks. *Howchinia* is at present only known from the English Carboniferous and is regarded as a derivative of *Cornuspira* Schultze. *Lasiotrochus* Reichel and *Lasciodiscus* Reichel both differ from *Howchinia* in possessing pillared umbilical plugs and in the extraordinary development of an outer coat of fringe-like processes. Both these genera may be derived from *Howchinia* and occur in the Upper Permian of Cyprus and Greece (Reichel, M., 1946, pp. 525–29).

Tetrataxis linea Ozawa (1925, p. 9, pl. 2, fig. 1) from the Upper Permian of Japan should be referred to the genus *Lasiotrochus* Reichel.

Considerable study of the genera *Trocholina* Paalzow and *Problematina* Borneman has been accomplished by Henson (1948, pp. 445–59) who has traced their ancestry to the genus *Cornuspira*. Further, Henson (*op. cit.*, p. 450) hints very strongly that a renewed study of *Howchinia* may reveal cornuspirine affinities.

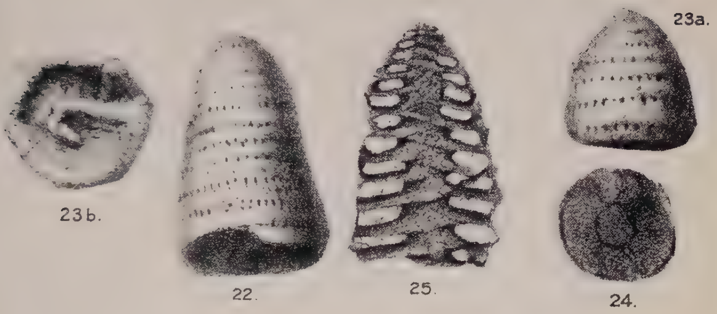
Trocholina is found in deposits believed to be of Triassic age and upward to the Cretaceous in the Middle East, while *Problematina* is well known in the Jurassic of Europe and Asia.

Palaeoecology. *Howchinia* is found associated with other foraminifera of the genera *Endothyra*, *Cornuspira*, *Cribrostomum*, *Tetrataxis*, etc., in thin limestones free from muddy or sandy contamination. In the high D_2 limestones it is often found associated with abundant dasycladaceous algae. In most cases associated foraminifera are present in considerable numbers and the circumstances suggest an ideal littoral free from sand, silt or black muds and close to or on the fringes of algal grounds.

3. PARTICULARS OF LOCALITIES

Below is arranged by counties, particulars of localities and sites, depths from O.D. at which specimens were recovered, and of stratigraphical horizons, where identified, and other relevant data.

The stratigraphical horizon shown in each case is that determined



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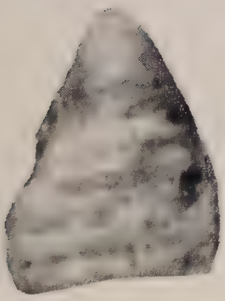

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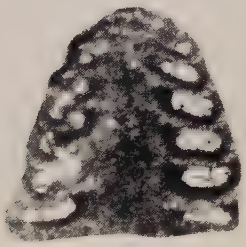

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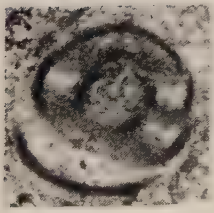

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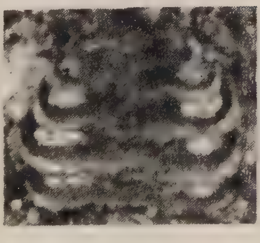

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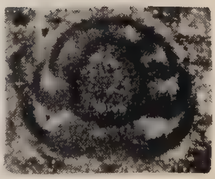

6.

Howchinia bradyana (Howchin), Lower Carboniferous

EXPLANATION OF PLATES

PLATE 10

Fig. 1. Howchin's original figures of *Patellina bradyana* 1888, 22 and 23a, side views; 23b, basal view; 24, section above base; 25, vertical section.

Figs. 2–6 *Howchinia bradyana* (Howchin).

Fig. 2. Lectotype. Side view. Tipalt, Northumberland. × 200. (P.40403.)

3. Topotype. Vertical section. Tipalt, Northumberland. × 200. (P.40342.)
4. Approx. horizontal section near base. Richmond, Yorks. × 200. (P.40407.)
5. Vertical section. Kirklington, Notts. × 200. (P.40408.)
6. Oblique equatorial section. Richmond, Yorks. × 200. (83914.)

PLATE 11

Figs. 1–10. *Howchinia bradyana* (Howchin).

Fig. 1. Sub-axial section. Richmond, Yorks. × 200 (P.40404.)

2. Axial section. Alport, Yorks. Depth 1204ft. × 200. (3690S.)
3. Approx. axial section. Aldfield, Yorks. Depth 427ft. × 200. (P.40405.)
4. Axial section. Alport, Yorks. Depth 1207ft. × 200. (BC3691S.)
5. Axial section, young individual. Widmerpool, Notts. Depth 4851ft. × 200. (P.40406.)
6. Approx. axial section. Richmond, Yorks. × 200. (63024.)
7. Approx. equatorial section about the third whorl, showing septa. Alport, Yorks. × 200. (3690S.)
8. Sub-axial section. Richmond, Yorks. × 200. (83914.)
9. Axial section, young individual. Richmond, Yorks. × 200. (83914.)
10. Axial section of young individual. Richmond, Yorks. × 200. (83914.)

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FIELD MEETING TO HAINAULT FOREST AND THE RODING VALLEY

Sunday, 8 April 1951

Report by the Director: John F. Hayward, Ph.D., M.Sc., F.G.S.

[*Received* 27 *July* 1951]

A PARTY of twenty-two members and friends assembled at Hainault Station. A bus was taken to near Chigwell Row on the edge of open country. Leaving Dog Kennel Hill (an outlier of Claygate Beds) on their right, the party climbed Cabin Hill where a good view of the nearby part of the Thames Valley was obtained. A small pit in an outlier of Bagshot Beds (Nat. Grid. Ref. 481939) contained fine buff-coloured sands with some narrow seams of pipe clay.

After lunch at Lambourne End the party proceeded to Abridge in the Roding Valley, seeing evidence of Boulder Clay and Pebble Gravel *en route*. At Abridge the meaning of the term 'flood plain' was only too evident. From here the road ran parallel to the Roding as far as Debden, where the river was crossed. Behind Debden (formerly Chigwell Lane) Station, excavations for building foundations permitted some examination of a patch of gravel mapped as Boyn Hill Terrace but which S. H. Warren (1942) had demonstrated as Pebble Gravel. Flooding made the trenches difficult to examine.

From here the party walked to Debden House, Further Education Centre, where tea was kindly provided by the Wardens, Mr. and Mrs. F. U. Hook. The party was then able to examine an exhibit by the Director illustrating the 'Geology of the Epping Forest and Lea Valley district'. The exhibit included material recently obtained from temporary sections in the area.

Mr. E. E. S. Brown, vice-president, proposed a vote of thanks to the Director, and to Mr. and Mrs. Hook. The party then walked to Loughton and dispersed.

REFERENCE

WARREN, S. H. 1942. The drifts of south-western Essex. Part 1. *Essex Nat.*, **17**, p. 162.

FIELD MEETING IN THE SOUTHERN CHILTERNS

Saturday, 28 April 1951

Report by the Director: H. L. Hawkins, D.Sc., F.R.S., F.G.S.

[*Received* 29 *June* 1951]

THIRTY members assembled at Reading Station and thence travelled by motor-coach.

The first stop was at Taplow, where the South Lodge pit, famous for its exposure of Phosphatic Chalk, was visited. Mr. N. R. Willcox, who is making an intensive study of the problem, demonstrated the sequence. The Chalk is completely flintless, and shows a remarkable condensation of zones, which range from that of *M. coranguinum* to that of *O. pilula* in a total thickness of less than thirty feet. There are two main seams of brown Phosphatic Chalk. The lower one, about four feet thick, rests on an indurated and eroded surface of Coranguinum Chalk riddled by 'borings' to a considerable depth. This seam represents the greater part of the Uintacrinus Zone. Above it, and sharply defined from it, come some twelve feet of very white chalk, 'marbled' throughout by tubular and irregular inclusions of brown phosphatic material. Most of this peculiar Chalk belongs to the zone of *Marsupites*. Its top is indurated, and coated with a veneer of glossy phosphate, which is encrusted by oysters. Then follows an eight-foot seam of Phosphatic Chalk (slightly less rich than the lower seam), in which plates of *Marsupites* occur near the bottom, and *Offaster pilula* higher up. This seam passes upwards gradually into white Chalk which is very unfossiliferous, but can be confidently ascribed to the zone of *A. quadratus s.l.*

The fauna of this Chalk is remarkable for the great abundance of belemnites (mostly referable to *Gonioteuthis granulata*) and the presence of large ammonites akin to *Parapuzosia. Echinocorys*, in a bewildering variety of forms, is common, and *Ostrea* crowds the horizons of non-sequence. The phosphatic seams contain enormous numbers of Foraminifera (mostly minute types), many of which are filled with phosphate but still retain their calcareous shells.

The reason for the abnormal and condensed development of the Chalk here is still obscure, especially since the available evidence points to a very limited lateral extent of the peculiarity. The concentration of high-zonal Chalk is preserved in a shallow bowl-syncline with a faulted eastern margin; but its production would seem to have been the result of a shoal-like elevation of the Cretaceous sea-floor, where currents inhibited the free accumulation of chalk. The whole succession is full of non-sequences and surfaces of contemporaneous erosion; and, to judge from the distribution of the zonal fossils, seems to have been frequently stirred up and rearranged.

Some time was spent in collecting samples of this remarkable Chalk, and before the party left Mr. Willcox gave a brief account of the present stage of his research.

The drive was then resumed across the plateau above Cliveden, from which a steep descent down the river-bluff led to Bourne End and Wooburn Green. Here the old chalk-pit near the railway station was examined. Most, if not all, of the Chalk exposed belongs to the zone of *M. cortestudinarium*; but in addition to the usual micrasters it reveals peculiarities in lithology and sedimentation. Several well-marked seams of marl traverse the Chalk in a disposition that appears to imply current-bedding. This presumptive evidence of shallow-water conditions may perhaps be linked with the more definite signs of shoal-water at Taplow; and it is consistent with the presence of an abnormal thinness and 'rockiness' of the zone of *H. planus* at Cliveden, mid-way between Taplow and Wooburn Green. If this interpretation is correct, the tendency to the maintenance of shallow water in the district (which culminated in the development of the Taplow phosphate) would seem to have persisted throughout the whole time of the Upper Chalk.

The journey was continued along the valley-road through Marlow to Medmenham, where a truly magnificent exposure of the Chalk Rock was seen in a roadside quarry. The rock is traversed by wide fissures that produce huge rectangular blocks; it is capped by a seam of tabular flint.

From Medmenham the party proceeded along the valley to Henley, and thence up the long dip-slope to Nettlebed, where tea was taken.

The return drive to Reading was by way of Peppard, and a brief halt was made at the Kennylands gravel-pit, where the relation of the gravel to the underlying Chalk, with differential solution causing irregular subsidence, showed the danger inherent in too precise calculations of terrace-levels. The great variety of pebbles occurring in the gravel was duly appreciated; but unfortunately the pit has been used recently as a dumping-ground for miscellaneous rubbish, and a considerable proportion of unnatural occurrences (notably ironstone from the Middle Lias) tends to confuse the record. In its present state the pit is of more value as a warning to the young than as a reliable guide to the Pleistocene.

THE ERRATICS OF THE ENGLISH CHALK

By L. HAWKES, D.Sc.

[*Received* 6 *September* 1950]
[*Read* 2 *February* 1951]

CONTENTS

	PAGE
1. Introduction ...	257
2. The Rock Types ...	258
3. Mode of Transport ...	262
4. Provenance ...	264
Description of Plates ...	266
References ...	266
Discussion ...	267

ABSTRACT.—A description is given of the Th. Wiltshire and G. E. Dibley Collections of erratics from the Chalk comprising 388 stones. Most of the specimens are small, from ½ to 5 cm. in length, only twenty are more than 9 cm. in length. The rock types represented include quartzitic sandstone, quartzite, quartz-schist, vein-quartz, chert, rhyolite, quartz-porphyry, granite, gneiss, tourmaline granite of luxulyan type, tourmalinised sandstone, phosphatic sandstone and limestone. The vein-quartzes are notable for strain and partial recrystallisation. The fossiliferous cherts have been examined by Dr. K. P. Oakley and Mr. C. D. Ovey who determine one as Carboniferous and others as probably Carboniferous.

The few larger stones more than 9 cm. in length may have been transported in the roots of trees or attached to seaweed, but many, and perhaps the majority, of the others are considered to be gastroliths picked up from pebbly beaches by marine reptiles (? plesiosaurs) and dropped from their drifting carcases. The 150 stones found within a few feet of one another at Rochester are probably the gastroliths of one reptile.

The erratics have been obtained from many and distant shores. The more specialised types among them indicate that the south-west of England and the Oslo Fjord–south-west Sweden region have contributed material.

1. INTRODUCTION

REFERENCES to finds of boulders and pebbles embedded in the English Chalk are scattered through the geological literature of the past hundred years and more. In 1858 Godwin-Austen described the occurrence of a collection of boulders and sand in the Chalk at Purley, near Croydon, and in his paper there is a discussion of the origin of these and other Chalk erratics. Since the introduction of the microscopic study of rocks W. P. D. Stebbing (1897) and I. S. Double (1931) have described boulders of quartzitic sandstone and granite from the Chalk at Betchworth. References to the literature are given by these two authors and Godwin-Austen. M. C. Janet (1891) and L. Cayeux (1897) have discussed the occurrence of stones in the Chalk of the Paris Basin. These boulders and pebbles have been called 'foreign stones', 'extraneous stones' and 'erratics'. The last-named term is preferred with the warning that it carries no implication of transport by ice. (An erratic is a stone which has been transported and deposited by some agent other than those which have laid down the fine sediment in which it occurs.)

The new material considered in the present paper was collected by Thomas Wiltshire and G. E. Dibley. The Wiltshire Collection of 212 stones is in the Sedgwick Museum, Cambridge, and I thank Prof. W. B. R. King for permission to study it and Mr. A. G. Brighton for much helpful assistance. The Dibley collection of 176 stones is in the Geological Survey and Museum, and Mr. Allen Howe, who had made a preliminary examination of it, kindly handed the work over to me. I am indebted to the Director of the Geological Survey for permission to work on this collection. In the following account the two collections are considered as a whole. One hundred and five specimens have been sliced, 67 from the Wiltshire and 38 from the Dibley collection.[1] Only 20 of the erratics (all of the Dibley collection) are more than 9 cm. in length; the largest is a cobble 20 x 10 x 9 cm. weighing 4 kgs., the specimen weighing 5 kgs. (Dibley, 1910) is missing. Most of the specimens are small, from 5 cm. to ½ cm. in length. Only the larger erratics have received detailed attention in the past, and in 1897 Salter observed that the smaller pebbles were worthy of study, being more numerous and of greater variety than the larger boulders and that they might, on microscopical examination, yield evidence as to their source of origin (Stebbing, W. P. D., 1897, p. 220). Salter can hardly have suspected that such a study would not be made for more than half a century!

The localities of many specimens are unknown. The large ones were found at Betchworth, and most of the Wiltshire Collection at Rochester and Gravesend—half of them were found within a few feet of one another at Rochester. Other localities are the Yorkshire Wolds, Norfolk (Harling), Cambridge (Isleham, Cherry Hinton), Surrey (Dorking, Warlingham), Kent (Burham, Charlton), Sussex (Lewes), Hampshire (Micheldever), Dorset (Man O'War Cove), and Devon (Beer). So far as the records go all come from the Lower and Middle Chalk. No particular significance can be attached to the abundance of the finds at different localities. The stones have been found where the Chalk has been worked, and where they have been especially looked for (Cayeux, L., 1897).

2. THE ROCK TYPES

The unsliced specimens appear to be mainly quartz rocks, cherts, and phosphatic pebbles. The sliced specimens are grouped as follows:

Vein-quartz	29
*Chert	20
Quartzitic sandstone	14
Phosphorite and phosphatic sediment	7
*Quartz schist	7
Granite	6
Quartzite	4
*Tourmaline-granite	3

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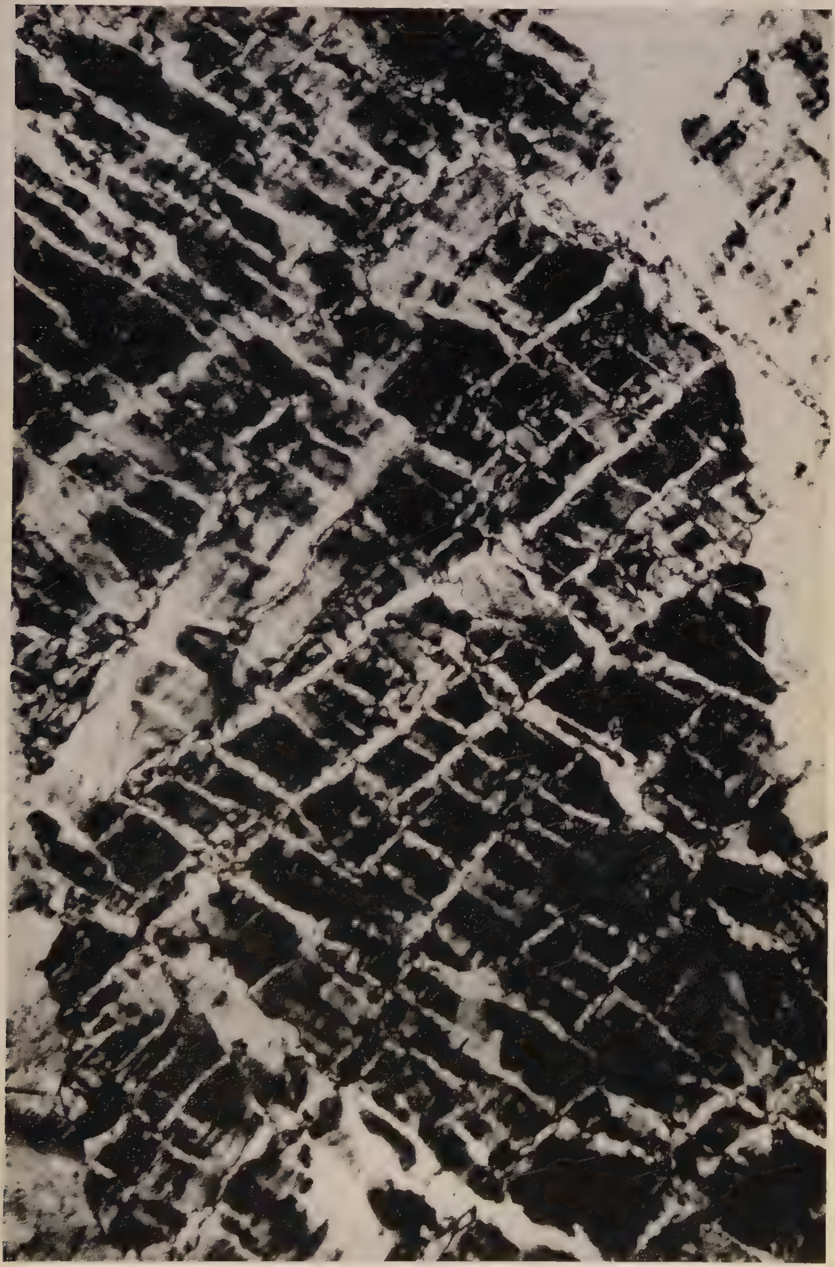
[1] Numbers labelled W. are of sections in the Sedgwick Museum; those labelled E.S. of sections (English series) in the Geological Survey and Museum.



Photomicrograph of Strained Vein-Quartz, Chalk Erratic.

[*To face page* 258.

*Rhyolite-porphyry	2 each
Micaceous sandstone	
Slate, Siltstone	
Glauconitic sandstone	
*Tourmalinised sandstone	1 each
*Quartz-porphyry	
*Glauconitic limestone	

* Not previously recorded among the Chalk erratics.

In the quartzitic sandstones the clastic grains can be distinguished from the quartz cement, the vein-quartzes are aggregates of larger crystals without cement, the quartzites show sutured interlocking without preferred orientation, whilst the quartz-schists are tectonites with a parallel elongation of crystals and a preferred optical orientation. In the following notes only special features are noticed which may be of value in tracing the source of the erratics.

The Vein-Quartz. Many of the pebbles are notable for the strain and recrystallisation phenomena exhibited in thin section. Strain is evidenced by undulose extinction, Böehm lamellae, ‘packet’ structure, and ‘lattice’ structure. The Böehm lamellae, close set and parallel or sub-parallel to the base, are marked by lines of inclusions, and commonly show a slightly different extinction giving the appearance of a fine multiple twinning (Plate 13, A and B). The lamellae are usually bent in sympathy with the undulose extinction which results from the deformation of the quartz by bending of the basal or sub-basal planes. In the ‘packet’ structure the crystal is resolved into a number of blocks with slightly different extinction. All the strain effects which have been described from vein quartz and quartzites in south-west Sweden are shown by the erratics (Holmquist, P. J., 1926).

The most striking strain effect is the ‘lattice’ structure (Adams, S. F., 1920, p. 648), which is best seen in sections parallel to the *c*-axis. With the crystal in extinction a grid is seen of two sets of diagonal sub-parallel lamellae which intersect at large angles and are not in extinction. In the photomicrograph (Plate 12) the *c*-axis of the host-crystal lies north, but is displaced *ca.* 38° to the west in the north-east lamellae and *ca.* 38° to the east in the north-west lamellae, so that, with the sensitive-tint plate, one set of lamellae is blue, the other yellow. The two sets of lamellae may be unequally developed and only one may be present. In ordinary light the lamellae appear as clear streaks in the turbid host-crystal. The orientation of the lamellae suggest that they mark shear planes diagonal to the direction of compression, and the displacement of their optical orientation is in the sense of drag along the shear planes. This lattice structure is under further study; this brief account will suffice to enable it to be recognised.

Partial recrystallisation of strained quartz is evidenced by the presence within single crystals of small ones, often in great numbers, with varying optical orientation (Plate 13, C). These inclusions tend to be euhedral when occurring singly, aggregates of them have a mosaic structure.[1] The new crystals are often preferentially developed at the boundaries of their hosts giving rise to mortar structure. The recrystallisation is an annealing effect (release of strain) and the new crystals are distinguished by their freedom from inclusions and their homogeneous extinction.

Strained crystals may be crossed by a grid of sub-parallel bands of recrystallised mosaic (Plate 13, D). The bands of mosaic exhibit a preferred orientation similar to that of the 'lattice' lamellae; and the two phenomena are clearly related.

Quartz-Schist. Four are pure quartz rocks; W.22 with a coarse mosaic structure and notable for the absence of strain, W.31, W.37 and E.S.20140 with sutured structures and undulose extinction. In E.S.20140 there is a strong development of Böehm lamellae.

W.35 and W.41 are strongly banded with parallel elongate slivers and augen of strained quartz in a fine grained recrystallised matrix. They are strongly sheared and largely recrystallised rocks, the result probably of plastic deformation without cataclasis.

W.41 is micaceous and the large augen contain lines of fine grained quartz with common optical orientation recalling the lattice structure of the strained vein-quartzes.

W.45 exhibits mortar structure due to peripheral recrystallisation of the grains, and it contains small rhombs, mostly opaque but with traces of highly birefringent remnants. In ordinary light W.63 shows films of mica and opaque material marking the boundaries of what were once augen quartzes. A few highly strained augen remain but most have recrystallised to a fine grained mosaic. Concentrations of muscovite may be pseudomorphs of kyanite.

E.S.20247 is a felspathic quartz-schist in which larger equidimensional and somewhat rounded microclines are set in a fine grained quartz matrix containing relics of long highly strained quartzes in alignment. The fine grained matrix is the result of the annealing recrystallisation of the quartz. Some of the felspars are fractured and smaller fragments are strewn in the quartz base. Under stress the quartz and felspar have behaved differently—the quartz suffering plastic deformation and the felspar a small degree of fracturing. The rock is in the main the result of flow and recrystallisation, not of cataclasis. Similar rocks have been described from the 'mylonite' belt above the Moine Thrust (*Geol. Surv. Memoir*, 1907).

The Cherts. These have not been reported by previous workers but they form a considerable proportion of the smaller erratics. Most of them are dark, some are cream coloured. Their shape and absence of white crust distinguishes them from the flints of the Chalk. Nineteen chosen at random were sectioned and ten of these are fossiliferous. I am indebted to Dr. K. P. Oakley for examining and reporting upon them and to Mr. C. D. Ovey for notes on the Foraminifera. Their reports are summarised as follows:

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[1] 'Mosaic' is here used in the strict sense of an aggregate in which the grain contacts seen in section are straight or slightly curved lines. Unfortunately the term is often loosely used for a sutured interlocking aggregate. No mosaic has the pattern of a jig-saw puzzle.

E.S.20143. Chert with numerous fragments of calcareous organisms, mainly Bryozoa (*e.g.*, *Fenestella* sp.) and Foraminifera (*Tetrataxis decurrens* (Brady), ? *Lituola* sp., *Climacammina* sp., and *Cribrostomum* sp.). Carboniferous, probably Lower.

E.S.20227, W.5, W.10, W.61. Spicular chert, probably Carboniferous.

W.8, W.26, W.53. Radiolarian chert (with *Cenospheara* sp.), probably Carboniferous.

W.33. Radiolarian chert (with *Thecosphaera* sp.), probably Carboniferous.

W.40. Radiolarian chert, probably Carboniferous.

The Radiolaria are particularly abundant in slice W.8, averaging 25 per sq. mm. Some of the cherts are impure finely laminated rocks with muscovite, tourmaline, quartz and, rarely, ghosts of rhombic carbonate.

Granites. W.46, W.56 and E.S.20246 are potash granites with dominant orthoclase, some oligoclase and biotite. The section E.S.20246, which is all that remains of an erratic 7 mm. across, has one large orthoclase perthite, with inclusions of oligoclase. E.S.20133 and 20135 are muscovite biotite crush granites approximating to gneiss, with oligoclase, microcline and orthoclase, and the quartz is highly strained; they resemble the granites described by W. P. D. Stebbing (1897) and I. S. Double (1931).

Tourmaline-Granites. In E.S.20146 the felspar is mostly orthoclase with some quartz in graphic intergrowth, and the tourmaline occurs as brown prisms with blue borders. The other two erratics were less than 1 cm. across and only the sections remain. E.S.20243 is a biotite-orthoclase granite with blue tourmaline. E.S.20132 is an orthoclase quartz rock with radiating aggregates of blue tourmaline needles in quartz replacing felspar, and it may be compared with luxulyanite. We may notice here a pebble (W.408) resembling tourmalinised killas from the upper part of the Chalk Marl at Isleham near Cambridge. It is an irregularly banded, quartz-veined, fine-grained sandstone, with feathery aggregates of blue-green tourmaline.

Rhyolite. E.S.20138 is a flow-banded porphyry with insets of sanidine in a base of micropoikilitic quartz and felspar laths; E.S.20136 is a devitrified obsidian porphyry. Euhedral insets of felspar (mainly orthoclase) and quartz are set in a fine-grained holocrystalline matrix which exhibits relict perlitic fractures.

Quartz-Porphyry. This erratic (E.S.20150, E.S.20235) is an unusual rock. It is much altered with insets of subhedral quartz and orthoclase-albite perthite. The quartz insets have fringes of lath-like outgrowths in optical continuity—the laths at any one face extending outwards at varying angles (Plate 13, E and F). Quartz laths are scattered through the groundmass giving what has been termed the reticulate structure (Geijer, P., 1913). Individual laths are commonly divided transversely into two or more sections with different optical orientation, and the extinction angle is variable. A plexus of laths may have a common optical orientation and the structure merges into that of micro-poikilitic quartz (*quartz globulaire épongeux*). These structures are shown by many Swedish Precambrian rhyolites (Geijer, P., 1913) and the fringed quartz of the erratic compares closely with that of the Ostersjo quartz-porphyry found as glacial boulders on the island of Gotland (Hedström, H., 1894, figs. 1, 2; pp. 252–3). This structure does not appear to have been described in rocks from Britain, but Dr. J. Phemister informs me that he has seen it in Old Red Sandstone igneous rocks from Scotland. Some development of fringed quartz is shown in the felsite from Carngryffe Quarry, Pettinain, Lanark (E.S.12670)—but the erratic is not this rock.

Silicified Shale. W.6 is a crumpled and partly silicified shale cut by highly sinuous veins of even-grained quartz mosaic.

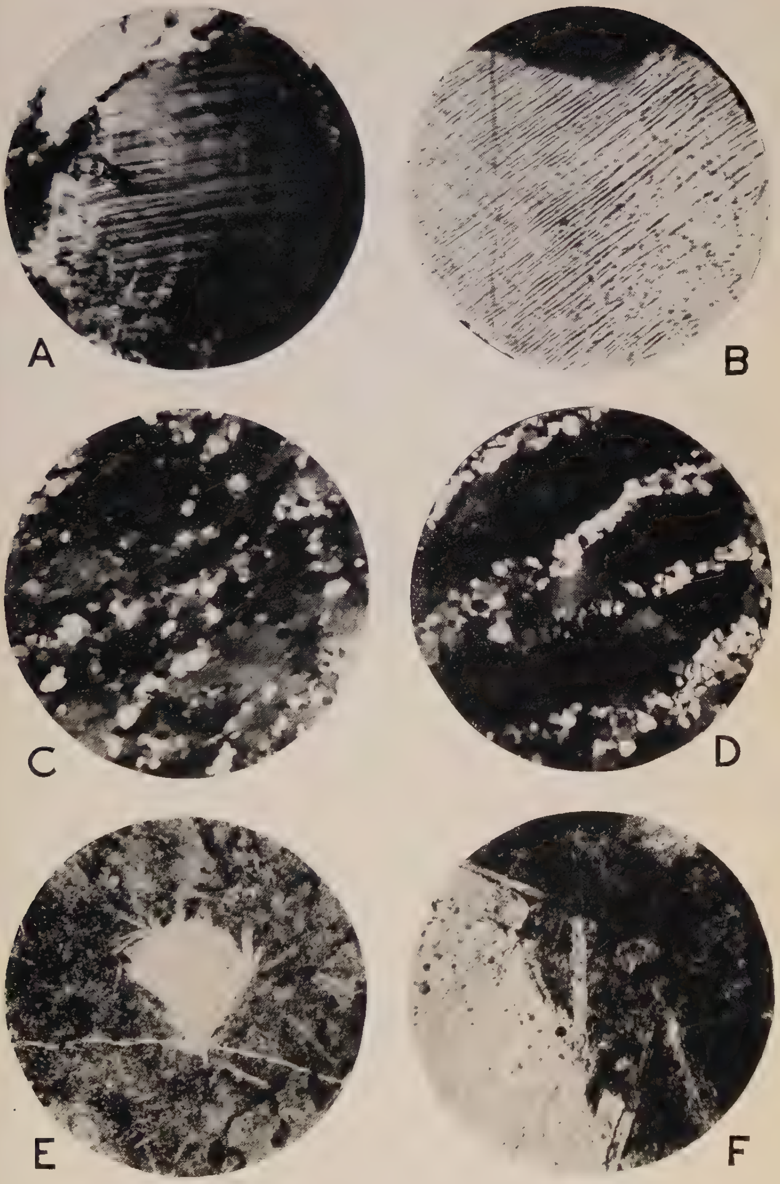
Phosphatic Rocks. Five of these are phosphorites largely composed of collophane with inclusions of quartz, glauconite and other detritals. E.S.20244 and E.S.20245 are glauconitic sandstones: in 20245 the phosphatic cement is reduced to a thin coating to the grains of a birefringent substance. Dr. Oakley reports that E.S.20236 contains Radiolaria (? *Lithocyclia* sp. and *Cenosphaera* cf. *ingens* Rust), Carboniferous, and that W.49 also contains Radiolaria (*e.g.*, *Trochodiscus* sp.) probably Carboniferous. Of W.65 he writes, 'Phosphorite with minute fragment of bryozoan resembling *Diplotrypa* sp. If this identification is correct the age of the erratic would be Ordovician or Silurian'.

Three of the erratics are partly phosphatised foraminiferal limestones, two with glauconite, and W.48 has holes bored in it. Mr. Ovey reports that W.30 contains '*Cristellaria*' sp., *Globigerina cretacea* d'Orb., abundant *Globigerina* spp. and *Gümbelina globulosa* (Ehrenb.). Upper Cretaceous (similar assemblage to that of the zone of *O. pilula*). W.48 contains *Globigerina* spp. and *Globotruncana* sp., Cretaceous.

3. MODE OF TRANSPORT

All possible agencies of transport, *viz.*, floatation over the sea by ice, in the roots of trees, attached to seaweed, and in the bodies of reptiles, were considered by Godwin-Austen (1858) in his masterly discussion of nearly a hundred years ago. The problem may be reconsidered in the light of our fuller knowledge today.

The agency of ice-transport has been invoked to account for the remarkable find at Purley near Croydon of a large boulder of granite together with smaller boulders of decomposed labradorite



Photomicrographs of various Chalk Erratics.

[*To face page* 262.

porphyry, sand from the breaking down of these rocks, and a quantity of siliceous 'fine water-worn beach sand' (Godwin-Austen, R., 1858, p. 257). The size of the large granite boulder was not accurately ascertained; the length of 3 ft. which has been cited (Woolnough, W. G., and T. W. E. David, 1926) may well be excessive. The fragments now in the Geological Survey and Museum would make a block 16 in. x 9 in. x 10 in. and weighing 45 lbs. Godwin-Austen writes: 'It is only with reference to such mixed assemblages of boulders, shingle and sand that the agency of ice is required, and we may feel sure that thousands of like cases are concealed in the mass of the Chalk.' However, no comparable occurrence has come to light in the last 90 years. Evidence from the Antarctic Ocean shows that the bottom deposits of seas, which carry drift ice, are characterised by a considerable admixture of sandy material derived from the ice as well as stray pebbles (Hough, J. L., 1950) and the general purity of the Chalk, which is also maintained in the neighbourhood of the erratics, renders any conception of the common presence of drift-ice untenable. No evidence is known of the existence of glaciers in north-west Europe in Cretaceous times; the indications are of a relatively warm climate (Hawkes, L., 1943). Godwin-Austen favoured the agency of drifted shore-ice to account for the Purley assemblage of erratics. If, as seems probable, these erratics have come from the Oslo region, it is difficult to conceive of shore-ice massive enough to survive a travel of 700 miles. If we may regard the sandy material as rock disintegrated in place, it is possible to accept the hypothesis of transport by seaweed or by tree roots—but the collection of the blocks in one place is difficult to understand. The occurrence is unique and it remains an unsolved puzzle.

Transport in the roots of trees or by drifting seaweed would account for the larger cobbles among the remainder of the erratics, and their well-rounded form, suggesting beach material, favours the seaweed agency. For the greater number of the erratics, which are 10 cm. and less in length, carriage in the bodies of reptiles is a possibility.

Many instances are now known of finds of plesiosaur bones associated with collections of pebbles embedded in stoneless fine-grained deposits and there can be no doubt that these pebbles are gastroliths (stomach-stones).

A specimen with seven pebbles, now in the British Museum (Nat. Hist.), was found in fine grained Upper Greensand (Codrington, T., 1866), and 'a peck (9 litres) of ovate and rounded pebbles' was found with the bones of a plesiosaur in the base of the Gault at Folkestone (Seeley, H. G., 1877). In North America many occurrences are reported from the Cretaceous rocks of both long- and short-necked plesiosaurs with pebbles; in one case 'the nearest place where the animal could have found such pebbles on the sea beaches must have been several hundred miles away. . . . We may conclude, hence, that the plesiosaurs were roving animals' (Williston, S. W., 1907, p. 76). Carcases may have drifted a considerable distance before deposition. With a plesiosaur in the Upper Cretaceous of South Dakota 253 gastroliths were found, totalling in weight over 8 kgs., the largest stone weighing 580 gms., the longest being 12·8 cms. and the shortest 1·1 cm. (Welles, S. P. and J. D. Bump, 1949, p. 253). Of another specimen enclosing 18 litres of stones Barnum Brown (1904) writes: 'Considering the weight of these stones the wonder is that so many specimens contain them. One would expect that when the flesh began to decompose the weight of these stones would be too great to be contained by the weakened tissues and that they would be lost before the animal reached its final resting place. This may well explain the absence of stones in some cases'—and, we may add, the presence of gastroliths without bones.

With the possible exception of a find of stones at Isleham 'mixed with material like rotten wood or decayed bones' (Jukes-Browne, A. J. and W. Hill, 1887) no bones have been reported in association with the Chalk erratics and those which are gastroliths must have been dropped from drifting carcases. It is noteworthy that two or more smaller stones have often been found together.

A chalk block 700 cc. in volume in the Wiltshire Collection contains 16 visible pebbles, and the label attached to it reads: 'All the pebbles marked "R" came from a pit near Rochester. They were in number about 150 and were found within a radius of 3 (? 6) feet.' One hundred and seven of these pebbles are in the collection. The largest (W.5) is 9·5 cm. long and weighs 250 gms. The 14 pebbles sectioned comprised 4 radiolarian and 2 spicular cherts (probably Carboniferous), 4 unfossiliferous cherts, 3 quartzitic sandstones, and 1 strained vein-quartz. There can be little doubt that these Rochester stones are gastroliths derived from one drifting carcase. They give the impression of having suddenly been emptied out of a bag—a stomach bag—on to the sea floor. Gastroliths may exhibit a high polish, especially the dinosaurian (Wieland, G. R., 1907), but it is not always present. Some of the cherts of the Rochester assemblage are highly polished, but most of the stones are not. A similar origin to that suggested for the Rochester stones has been advanced for a group of pebbles found in the Upper Cretaceous limestone (Mucronatakritan) in north-eastern Scania (Wiman, C., 1916).

4. PROVENANCE

The phosphatic glauconitic sandstones and the glauconitic sandy limestone are probably of Cretaceous age and their presence is not surprising as it is known that Lower Cretaceous rocks were being eroded in Chalk times (Robbie, J. A., 1950). Professor A. Noe-Nygaard has a collection of 20 erratics from the Senonian and Danian deposits of Denmark, and he states in a letter to me (October 1949): 'The greater part of the material consists of sandstones with glauconite, as far as I can make out derived from shore deposits or older sediments of Cretaceous age.' Apart from these all the erratics (and the overwhelming majority of the English ones) have a Palaeozoic and Pre-Palaeozoic 'look': the Carboniferous age of some is proved. The stones comprise a great variety of rock types, highly resistant quartz rocks being in the majority. The absence of limestones is noteworthy. As general stratigraphic studies would lead us to expect, the shores of the Chalk sea were composed of the older rocks of the stratigraphic column.

The precise determination of provenance is a hazardous undertaking. The erratics may have been transported for long distances—hundreds of miles—and an examination of the maps drawn by different stratigraphers to indicate the extent of the Chalk seas will demonstrate the wide choice of sources. Proximity to the shore is not necessarily a controlling factor. Nor can the conception of current drift be invoked to elucidate the distribution and association of rock types as in all probability the majority of the stones are gastroliths, collected by roaming reptiles from many shores and transported independently of current control. Most of the rock types have a wide distribution and the attribution of the quartzitic sandstones to the Bunter Pebble Beds of the Midlands (Double, I. S., 1931) and those of the Paris Basin to the Ardennes rocks (Cayeux, L., 1897) belongs to the realm of possibility, not probability. Even the occurrence of the more specialised rock types represented may not be so narrowly localised as present knowledge indicates. Thus the remarkable strain effects shown by many of the quartz erratics, particularly the vein-quartz, have not been described from British rocks, but they may occur—it is not usual to section vein-quartz. Bearing in mind the reservations imposed by the foregoing considerations, two areas may be considered to have contributed to the assemblage of erratics; the south-west of England, and the Oslo Fjord–south-west Sweden region.

The luxulyanite type of granite, other tourmaline granites, the tourmalinised sandstone, the fossiliferous cherts of Culm type, the silicified quartz-veined slate, and many of the vein-quartz pebbles could all have come from the south-west of England. The inference that there was land here in Lower and Middle Chalk times is supported by the presence of minerals from west-of-England granites in the Chalk of south-west England (Groves, A. W., 1931). I have examined some of the quartz veins in the Culm and Devonian rocks of North Devon and Cornwall. Some sections reveal considerable strain, but in none is this so marked as in many of the erratics. The granite 'Boulder B' described by Stebbing, 1897, is not a Dartmoor rock, however, and the conclusion which has been drawn from it of the presence of a glacier on Dartmoor cannot be accepted (Martin, E. A., 1897).

From its appearance in hand specimen D, Forbes suggested that the large granite boulder found at Purley was a Scandinavian rock

(Godwin-Austen, R., 1858, p. 256) and in thin section the texture with euhedral perthites is seen to be that characteristic of the syenitic and granitic rocks of the Oslo region. The dark minerals are altered beyond recognition but a section (17253) in the Harker Collection at Cambridge contains aegerine preserved by enclosure in quartz. The pebbles found with this boulder are highly weathered porphyries with large tabular felspars recalling the essexite lavas of the Oslo region. One fresh 'greenstone' from Purley in the Dibley Collection (E.S.119) is an altered olivine labradorite porphyry, with actinolite and epidote, and V. M. Goldschmidt, to whom it was shown in 1943, agreed that it might well be a hydrothermally altered essexite lava of the Oslo region. The distinctive rhyolites with reticulate and micro-poikilitic quartz and the highly strained vein-quartzes and quartzites are all known to occur in the adjoining region of south-west Sweden. It is tempting to see, in the Ostersjo porphyry of Gotland, the source of the porphyry erratic with the fringed quartz, but perhaps this is to stray too far outside the realm of probability. It is to be hoped that a microscopic examination will be made of the erratics of the Danish Chalk to see if any of these rock types are represented.

DESCRIPTION OF PLATES

(All are photomicrographs of sections of erratics.)

PLATE 12

Strained vein-quartz. W.17 C. X'd N. Length 2 mm. Quartz crystal showing lattice structure. The host crystal is in extinction. The orientation is displaced 38° to the west in the north-east set of lamellae, and 38° to the east in the north-west set. (The direction 'north' is normal to the length of the crystal.)

PLATE 13

A. Strained vein-quartz. Rochester. W.12. X'd N. Diameter 0·5 mm. Quartz crystal 11 'c', undulose extinction. The bent lamellae are approximately parallel to the base. The difference in extinction of the two series of bands is 7°.

B. The same rock. W.12 (1). X'd N. Diameter 1 mm. Quartz 11 'c'. Böehm lamellae. The darkness of alternate bands is due to minute inclusions.

C. Partially recrystallised vein-quartz. Southerham Pit, Lewes. W.23. X'd N. Diameter 1·9 mm. One strained quartz crystal in extinction containing a large number of small quartzes resulting from annealing recrystallisation.

D. The same rock W.23 (A). X'd N. Diameter 2 mm. The host quartz crystal is in extinction, and contains sub-parallel bands of recrystallised quartz mosaic with preferred optical orientation.

E. Quartz-porphyry. E.S.20150. Ord. L. Diameter 1·3 mm. Fringed quartz inset.

F. Same section. X'd. N. Diameter 0·4 mm. Detail of the fringe of part of a quartz inset.

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DISCUSSION

MR. K. A. JOYSEY said that, with reference to Professor Hawkes' suggestion that many of the erratics from the Chalk are gastroliths (or stomach-stones) of plesiosaurs, it is of interest to consider whether these stones were deliberately or accidentally acquired. It is perhaps unnecessary to rely entirely upon plesiosaurs as a means of animal transport, for fish are also known to carry stones. Examination of the stomach contents of bottom-feeding elasmobranchs, such as the Common Skate (*Raia*), reveals the presence of pebbles which are probably unintentionally injested in the search for food. Shellfish weighing some 3 lb. have been found in the stomach of the present-day Eagle Ray (*Aetobatus*) and attached pebbles must often be included when food of such bulk is taken from the sea floor. Teeth of the closely related genus *Ptychodus* are well known from the Chalk, but the main skeletal structures of such fish are cartilaginous, and therefore unlikely to be preserved as fossils. Should these fish be in part responsible for the distribution of pebble erratics, it is possible to understand the usual absence of associated bones.

PROFESSOR HAWKES, in reply, agreed with Mr. Joysey that some gastroliths may have been carried by creatures other than plesiosaurs. He cited the plesiosaurs because it was known that they did carry stones of such a size and in such an amount as found at Rochester. He hesitated to express an opinion about the intentions of Cretaceous plesiosaurs. They were roving animals and presumably lived on the fish swimming in the sea. He was unaware of any evidence of their having obtained their food from the shore.

FIELD MEETING IN SHEPPEY

Saturday, 16 June 1951

Report by the Directors: A. G. Davis, F.G.S. and G. F. Elliott, F.G.S.

[*Received* 9 *July* 1951]

TWENTY-NINE members and friends assembled at South Kensington and proceeded to Sheppey, being joined by one member at Rochester and four more on arrival. Lunch was taken on the cliff at Warden Point, where one of the directors (G.F.E.) gave a brief account of the local geology and palaeontology and of the historical development of these studies. Dealing with the very rapid coast erosion at this spot, it was mentioned that if the members of this, the ninth excursion of the Association, could see their predecessors of the first (1861), they would behold them some 300 yds. out to sea and 140ft. above the waves, the whole of this mass of land having fallen away in the last ninety years, including the site of Warden Church, which was seen by the Association in 1875 at the cliff-edge. Descending to the beach, search was made for fossils in the pyritic and septarian accumulations there; it was noted by the directors and others familiar with Warden Point and Bay, that specimens were much less abundant than in former years, no doubt due to the fact that the heavy cliff-falls of the previous winter had not yet been fully washed away and sifted by the tides. The party proceeded westwards, collecting *en route*, to Barrow Brook, where Mr. D. Curry drew attention to the anomalous bedding in cliff and foreshore as indicated by septaria and pyrites: this, being the stable cliff of Davis's division *b* (*Proc. Geol. Assoc.*, 1936, **47**, p. 330), was considered to indicate a possible fold, fault, or similar disturbance, rather than slumping. The directors commented on the very marked erosional effect of the tiny stream here on the clay near the coast, and a local member, Mr. H. Cameron, mentioned that in wet weather visible movement of the slumping clay occasionally occurred. Ascending the gorge, the party returned by the cliff-path, noting the cracks presaging further slips. Tea was taken in the garden of Warden Post Office. It was found that a fair selection of the commoner fossils had been collected by the party as a whole; unusual finds included a septarian nest of echinoids and an eighth or ninth century dog-headed bronze pin. One of the directors (A.G.D.) exhibited a small selection of early books dealing with Sheppey.

A vote of thanks to the directors and excursion secretary, Miss J. M. Spires, was proposed by Mr. W. N. Edwards, and the party returned to London.

NOTE ON A DERIVED BOULDER AT WARDEN POINT

By A. G. DAVIS, F.G.S.

[*Received* 9 *July* 1951]

IN June 1949 a boulder of non-calcareous buff-coloured quartzitic sandstone, measuring roughly nine by four inches, was found at the foot of the cliff. The surfaces were irregular and slightly water-worn and its appearance showed that it had not been in contact with the present tides nor entombed in the London Clay. It was packed with molluscan casts—*Cyrena cuneiformis*, *Cyrena* sp. (large form) and *Brotia inquinata*, forms characteristic of the Woolwich and Blackheath Beds. These species are notably absent from the Oldhaven Beds at Herne Bay but are known at Upnor and from the ironstones of Blean (Oldhaven Beds). The lithology is, however, unlike any known in Kent but may be regarded as similar to the shelly sandstone (?Oldhaven Beds) dredged from Harwich Harbour. Immediately above the site, where the boulder was found, are some small pockets of Bagshot pebbles and it is reasonable to suppose that it had fallen from one of these.

NOTE ON THE OCCURRENCE OF MANGROVES IN THE LONDON CLAY

By M. E. J. CHANDLER

[*Received* 9 *July* 1951]

IN 1933 Reid and Chandler, after an intensive study of the London Clay Flora, were convinced that it was mainly of a tropical rain-forest type. The most abundant plant at Sheppey was the nipa palm (*Nipa burtini* Brongniart) represented by numerous fruits. More recently the fruits have also been found in a fair degree of abundance at Herne Bay. *Nipa* at the present day is confined to the salt-water swamps and tidal-river banks of South-east Asia, growing in situations where at low tide the water is almost fresh. As it is a characteristic constituent of the mangrove-swamps we naturally looked, but in vain, for some evidence of Rhizophoraceae, the typical mangroves, among the associated plant remains.

Lately, however, Mr. D. J. Jenkins's assiduous collecting at Herne Bay has been rewarded by the discovery of several fruits apparently closely related to the genus *Bruguiera*. The first specimen received was not at first recognised but was put aside as a piece of wood. But when several other similar 'fragments' appeared, the fine regular cell-structure of the epidermis, and the distinct circular scar at one end, suggested that further search should be made in order to establish the nature and relationship of these specimens. Eventually they were identified as the cigar-shaped viviparous fruits of Rhizophoraceae. The short stout straight radicle pointed to affinity with *Bruguiera*, the circular scar at the blunt end being left by the now decayed or fallen perianth. In *Bruguiera* the calyx falls with the fruit, but soon becomes detached.

Two quite distinct species were found at Herne Bay. The determination from superficial characters was confirmed by a careful study of the cell-structure in longitudinal and transverse section. The longitudinal section displayed one highly characteristic feature, namely, numerous short, very straight bead-like rows of thin-walled globular cells, the cells at the middle of each row being the largest, the size gradually diminishing towards the ends of the rows. These bead-like rows of cells can be exactly matched in living material.

The discovery at Herne Bay led to the recognition of yet a third species of mangrove at Sheppey, among material collected by Mr. A. G. Davis at Warden Point. It is represented by fragments of the long, curved and angled radicle, usually from near the narrow extremity, although in the greater number of fossils the extreme tip is broken or abraded. These were at first thought to be angular fleshy leaf-fragments, but the examination of their structure in detail made it clear that they too belonged to the Rhizophoraceae, though to a different genus, such as *Ceriops*. A detailed description of these species will eventually appear in one of the forthcoming volumes on *The Tertiary floras of Southern England* to be published by the British Museum (Natural History).

This is the first English record of the family with which I am acquainted. It is interesting to note, however, that it has been recognised from wood (*Gynotrochoxylon africanum* Kräusel) in the Lower Oligocene of Egypt (Kräusel, 1939, *Abh. Bayer. Akad. Wiss.* (n.f.), **47**, p. 97, pl. 22, figs. 1–3; text-fig. 29) and from pollen of the *Rhizophora*-type in the Upper Cretaceous Flysch near Salzburg (Hofmann, 1948, *Phyton*, Graz, **1**, p. 80, text-fig. 1).

INDEX TO VOLUME 62

PAGE
Actinocamax quadratus, Zone of 63
Adur, Valley of the 31
ALFRED JOSEPH BULL, M.Sc., Ph.D., F.G.S., 1876–1950. [Obituary]. By J. F. KIRKALDY and E. E. S. BROWN 1
Ammonoidea from Gault–Lower Greensand junction 97
Analysis of Clacton industry ... 133
Angular Flint Gravel to Clay-with-Flints, Osmington, Relation of 29
Annual Report of Council for 1950 65
Anvil-stones, Clacton industry... 126
Ardennes during Carboniferous and Devonian 155
ARKELL, W. J. The structure of Spring Bottom Ridge, and the origin of the mud-slides, Osmington, Dorset 21
Armorica 143
Armorican Massif 157
Asturias, Carboniferous of ... 147
————, ———— and Devonian of 160
Axe-edged tools, Clacton industry 115

BALL, H. W. The Silurian and Devonian rocks of Turner's Hill and Gornal, South Staffordshire 225
Balsdean Inlier 36
BARTH, T. F. W. (and others). Summer Field Meeting in Norway 203
Beddingham Anticline 35
Biface working, Clacton industry 111
Bone implements, Clacton industry 129
BRAY, A. The decomposition of iron pyrite from coal seams 136
BROWN, E. E. S. (and J. F. KIRKALDY). Joseph Alfred Bull. [Obituary] 1
Bulb characters, Clacton industry 124
BULL, ALFRED JOSEPH. [Obituary]. By J. F. KIRKALDY and E. E. S. BROWN ... 1

Carboniferous of Western Europe and North Africa 141, 154

PAGE
Castle Hill and Seaford Synclines 36
Cataclasis in acidic dykes ... 237
———— of granite and pegmatite in gabbro 243
Central Massif, France ... 146, 159
Chalk erratics 257
———— Marl 41
CHAMPION, A. M. [Obituary] 85
CHANDLER, M. E. J. Note on the occurrence of mangroves in the London Clay 271
CHANNON, P. J. A new section at Cowcombe Hill, near Chalford Station, Glos., exposing the junction of Inferior Oolite and Fuller's Earth 174
Chloritic Marl 40
Choppers, Clacton industry ... 114
Clacton Bed, Analysis 133
————, Correlation of ... 130
Clacton flake 124
———— flint industry: A new interpretation. By S. HAZZLEDINE WARREN (Second Henry Stopes Memorial Lecture) 107
———— man, A user of fire? ... 128
Clay-with-Flints. Relation of Angular Flint Gravel to ... 29
Coal seams, Decomposition of iron pyrite from 136
Colddean and Lower Bevendean Inlier 36
Colomb-Bechar–Kenadsa region, Carboniferous of 150
Cores, Clacton industry ... 125
Corrected National Grid references to 'New and enlarged Jurassic sections in the Cotswolds'. By P. J. CHANNON, *Proc. Geol. Assoc.*, 1950, **61**, 242–60 176
Cowcombe Hill, junction of Inferior oolite and Fuller's Earth 174
CRAMP, A. W. [Obituary] ... 85
Cromer Ridge 105
Crystal growth in coal seams ... 139

DANIELS, F. L. [Obituary] ... 86
DAVIS, A. G. *Howchinia bradyana* (Howchin) and its distribution in the Lower Carboniferous of England 248

PAGE

DAVIS, A. G. Note on a derived boulder at Warden Point ... 270
——— and G. F. ELLIOTT. Field meeting in Sheppey ... 269
Decomposition of iron pyrite from coal seams. By A. Bray 136
Devonian of Western Europe and North Africa ... 140, 154
——— rocks of South Staffordshire 225
Discoidal forms and flake-discs, Clacton industry 115
Ditrupa bartonensis n. sp. ... 191
——— *plana* (J. Sowerby) ... 190
Djerada, Carboniferous of ... 150
DODD, F. H. [Obituary] ... 86
Dorset, Structure of Spring Bottom Ridge, and the origin of the mud-slides, Osmington 21
Downton Castle Sandstone Group 230
——— Series, South Staffordshire 226, 230
DURY, G. H. A 400-foot bench in South-eastern Warwickshire 167

East Midland Group Report ... 83
EASTWOOD, T. Roofing materials through the ages ... 6
Edge-chipping, Clacton industry 127
ELLIOTT, G. F. (and A. G. DAVIS). Field Meeting in Sheppey 269
End-Moraine north of Flamborough Head. By A. Farrington and G. F. Mitchell 100
English Chalk, Erratics of ... 257
Eocene Serpulids 177
Erratics of the English Chalk. By L. Hawkes... 257

Faceting, Clacton industry ... 109
FARRINGTON, A. and G. F. MITCHELL. The end-moraine north of Flamborough Head 100
——— (discussion) 106
Field Meetings, 1950 79
Flake-discs, Clacton industry ... 115
Flake-points, Proto-Mousterian, Clacton industry 120
Flakes 120
Flaking-angle, Clacton industry 108, 120
Flamborough Head 100

PAGE

Foulerton Award ... 66, 69
[Four hundred] 400-foot bench in South-eastern Warwickshire. By G. H. Dury... ... 167
France, Carboniferous of Central Massif 146
Franco-Belgian area, Carboniferous of 141
Friar's Bay (Newhaven) Anticline 36
Fuller's Earth and Inferior Oolite junction 174

Gabbro, Mylonitisation and cataclasis in 237
GASTER, C. T. A. The structure of the Chalk of Sussex. Pt. IV. East Central Area—between the Valley of the Adur and Seaford, with zonal map 31
Gault–Lower Greensand junction 95
Geology of the area between the Finse district and the Bergen arcs. By A. Kvale 214
——— district around the upper part of Oslo Fjord. By O. Holtedahl and T. F. W. Barth 211
Glynde Syncline 35
Gornal Sandstone 231
———, South Staffordshire ... 225
GORDON, W. T. [Obituary] ... 86
Granite erratics in Chalk ... 261
GREGORY, H. H. [Obituary]... 88

Hainhault Forest and the Roding Valley, Field Meeting... ... 254
Hardangerfjord, Area to east of 214
———, Area to west of ... 217
HARGREAVES, J. [Obituary] 89
HAWKES, L. The erratics of the English Chalk 257
HAWKINS, H. L. Field Meeting in the Southern Chilterns ... 255
HAYWARD, J. F. Field Meeting to Hainhault Forest and the Roding Valley 254
Henfield Syncline 33
Holaster planus, Zone of ... 46
——— *subglobosus*, Zone of ... 42
Hollingbury Anticline 34
HOLLINGWORTH, S. E. (discussion) 106
HOLTEDAHL, O. (and others). Summer Field meeting in Norway 203

PAGE
Howchinia bradyana (Howchin) and its distribution in the Lower Carboniferous of England. By A. G. Davis 248
HUGHES, A. B. [Obituary] ... 89

Inferior Oolite and Fuller's Earth junction 174
Inoceramus labiatus, Zone of ... 43
Insch Gabbro (Aberdeenshire)... 237
Iron pyrite, Decomposition from coal seams 136

JEFFERY, H. J. [Obituary] ... 90
JOHNSON, W. [Obituary] ... 91
JOYSEY, K. A. (discussion) ... 267

KENNARD, A. S. Opinions on Clacton Mollusca expressed by the late 131
Kingston near Lewes Anticline... 34
KIRKALDY, J. F. and E. E. S. BROWN. Joseph Alfred Bull. [Obituary] 1
——— (with others). Summer Field Meeting in Norway ... 203
KOLDERUP, N.-H. (with others). Summer Field Meeting in Norway... 203
KVALE, A. Geology of the area between the Finse district and Bergen arcs 214
——— (with others). Summer Field Meeting in Norway ... 203

Library, Report 67
———, Donations during 1950 83
London Clay, Mangroves in ... 271
Lower Bevendean Inlier... ... 36
——— Carboniferous, *Howchinia bradyana* in 248
Ludlow Bone Bed 230
——— Series, South Staffordshire 226

Mangroves in the London Clay 271
Micraster coranguinum, Zone of 51
——— *cortestudinarium*, Zone of 48
Midland Group, Report ... 82
MITCHELL, G. F. (and A. FARRINGTON). The end-moraine north of Flamborough Head 100
Montagne Noire, Carboniferous of 146
Morocco, Carboniferous of ... 150
MORRIS, T. G. [Obituary] ... 92

PAGE
Mount Caburn Syncline ... 33
Movements of the late Palaeozoic Seas in Western Europe and North Africa 154
Mylonitisation and cataclasis in acidic dykes in the Insch (Aberdeenshire) Gabbro and its aureole. By H. H. Read ... 237
———, acidic intrusions ... 239
Mylonitised granite at Knockollochie 239
——— porphyrite at Westhall, Aberdeenshire... 242

New Section at Cowcombe Hill, near Chalford Station, Glos., exposing the junction of Inferior Oolite and Fuller's Earth. By P. J. Channon ... 174
Newer Drift topography, Flamborough area 102
Nodule tools, Clacton industry... 111
North Africa, Carboniferous of 150
———, ——— and Devonian of 154, 161
North-east Lancashire Group, Report 81
North Staffordshire Group, Report 82
Norway Field Meeting 203
Note on a derived boulder at Warden Point. By A. G. Davis 270
——— the occurrence of Mangroves in the London Clay. By M. E. J. Chandler... 271

Offaster pilula, Zone of 60
Older Drift topography, Flamborough area 104
Opinions on Clacton Mollusca expressed by A. S. Kennard ... 131
Origin of mud-slides, Osmington, Dorset 27
Oslo Fjord, Geology of the upper part of 211
Osmington, Dorset 21
——— mud-slides, Origin of ... 27

Palaeoecology of *Howchinia bradyana* 250
Patination and abrasion, Clacton industry 110
Phosphatic rocks as erratics in Chalk 262
Presidential address (Roofing materials through the ages). By T. Eastwood 6

PAGE
Protula episcopalis n. sp. ... 193
——— *extensa* (Solander) ... 192
Provenance of Chalk erratics ... 264
Pyecombe Anticline 33
Pyrenees, Carboniferous of ... 146

Quartz-porphyry erratics in Chalk 261
———-schist erratics in Chalk 260

Red Downton Beds, South Staffordshire 233
Report of Session, 1950... ... 74
Reunion, List of Exhibits ... 78
Rhyolite erratics in Chalk ... 261
Roding Valley, Field Meeting ... 254
Roofing materials through the ages. By T. Eastwood. [Presidential address] 6
Rotularia bognoriensis (Mantell) 178
Rottingdean Syncline and Saltdean Anticline 36

Sahara, Carboniferous of ... 153
Saltdean Anticline 36
Schloenbachia varians, Zone of... 40
Sclerostyla Mørch 184
——— *gallica* n. sp. 187
——— *mellevillei* (Nyst and Hon) 185
——— *perforata* n. sp. ... 187
?——— sp. 189
——— *trochoides* (Nyst) ... 188
Scrapers, Clacton industry 115, 117
Seaford 31
——— Head Anticline ... 36
——— Syncline 36
Sedgley Limestone 227
Serpula Linnaeus 190
——— *crassa* J. Sowerby ... 190
Serpulid tubes, Essentials of ... 193
Sheppey Field Meeting 269
SHOTTON, F. W. (discussion) 173
Silicified shale erratics in Chalk 262
Silurian and Devonian rocks of Turner's Hill and Gornal, South Staffordshire. By H. W. Ball 225
Some Eocene serpulids. By A. Wrigley 177
Southern Chilterns, Field Meeting 255
Spring Bottom Ridge, Structure of 21
Stopes Memorial Fund 66
Striation, Clacton industry ... 128
Structure of Cretaceous syncline, Osmington 24

PAGE
Structure of Spring Bottom Ridge, and the origin of the mud-slides, Osmington, Dorset. By W. J. Arkell ... 21
———s in Upper Jurassic and Wealden rocks, Osmington ... 23
Studies of the Devonian and Carboniferous of Western Europe and North Africa. By G. Delépine 140
Summer Field Meeting in Norway. By the Directors... ... 203

Tafilalet, Carboniferous of ... 151
Telscombe Syncline 36
Temeside Beds, South Staffordshire 232
Terebratulina lata, Zone of ... 45
TOMLINSON, M. E. (discussion) 173
Tourmaline-granite erratics in Chalk 261
Transport of erratics in Chalk ... 262
Trimmed flakes, Clacton industry 115
Turbinia abbreviata (Deshayes)... 189
Turner's Hill and Gornal, South Staffordshire 225
——— Beds 231

Uintacrinus, Subzone of... ... 55
Upper Ludlow Shales, South Staffordshire 228
——— Jurassic and Weald–Rocks, Structures in, Osmington 23
Utilisation, Clacton industry ... 128

Vein-quartz erratics in Chalk ... 259
Vosges, Carboniferous of ... 146

Warden Point, Derived boulder at 270
WARREN, S. HAZZLEDINE. The Clacton flint industry: A new interpretation 107
Warwickshire, A 400-foot bench in south-eastern 167
WATT, W. R. [Obituary] ... 92
Weald Research Committee, Report of 67
——— Report No. 43 ... 95
Wealden rocks, Osmington, Structures in 23
Western Europe, Carboniferous and Devonian of ... 140, 154

PAGE
WILLS, R. G. [Obituary] ... 93
Wooden spear, Clacton industry 129
Wrecclesham, Surrey 95
WRIGLEY, A. Some Eocene serpulids 177

PAGE
Young Fund, Awards 66
Zonal position of the Gault–Lower Greensand Junction Beds at Wrecclesham, Surrey. By R. CASEY 95